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THESIS

ESTIMATING THE FULLY BURDENED COST OF FUEL FOR A NAVAL AVIATION FIXED WING PLATFORM

by

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June 2010

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This thesis provides the background and motivation for furthering the Fully Burdened Cost of Fuel (FBCF) cost estimating methodology and calculations in the context of a naval aviation fixed wing platform. The FBCF contribution to Total Ownership Cost in the Analysis of Alternatives for Major Defense Acquisition Programs requires steady advancement to meet an October 2011 implementation deadline.

Applying OSD guidance and calculator mathematical process facilitates comparison of the additional costs to deliver and protect fuel demanded by the F/A-18E/F aircraft with those added costs for a ship platform. Total costs throughout a realistic operation and support life cycle and applying a notional scenario to the newest calculator demonstrate a range of cost estimating methods.

Our conclusions support previous analysis that air refueling contributes significantly to logistics support costs and that investment in fuel conservation technologies and platform endurance can be a strategic opportunity for the Department of Defense and the Department of the Navy. The aircraft FBCF is multiple times higher than the fuel commodity price as compared to the FBCF for ships, which is only fractionally higher than the fuel commodity price. Assured Delivery Price of supplied fuel calculations are complicated for platforms that require multiple refueling support assets.

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ESTIMATING THE FULLY BURDENED COST OF FUEL FOR A NAVAL AVIATION FIXED WING PLATFORM

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This thesis provides the background and motivation for furthering the Fully Burdened Cost of Fuel (FBCF) cost estimating methodology and calculations in the context of a naval aviation fixed wing platform. The FBCF contribution to Total Ownership Cost in the Analysis of Alternatives for Major Defense Acquisition Programs requires steady advancement to meet an October 2011 implementation deadline.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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EXECUTIVE SUMMARY

The Defense Acquisition Guidebook (DAG) defines Fully Burdened Cost of Fuel (FBCF) as “The cost of the fuel itself (typically the Defense Energy Support Center (DESC) standard price) plus the apportioned cost of all of the fuel delivery logistics and related force protection required beyond the DESC point of sale (POS) to ensure refueling of the system” (Defense Acquisition University, 2009). FBCF is a direct contributor to the Total Ownership Cost (TOC) used in the Analysis of Alternatives (AOA) phase of the Defense Acquisition System process. The analytical method developed by Office of the Under Secretary of Defense for Acquisition, Technology and Logistics to estimate FBCF includes seven distinct cost elements.

Numerous studies have informed the guidance and policies created for FBCF. The Defense Science Board (DSB) recommended accelerated efforts to use FBCF as a factor in all AOA through acquisition tradespace, claiming the “acquisition process does not properly value energy efficiency and hence programs are designed that consume too much of it" (DSB, 2008). The LMI Government Consulting group solution to this problem was to implement a comprehensive Department of Defense (DoD) energy strategy including two key supporting actions that indicate the strategic value of FBCF:

1) Implement the use of fully burdened fuel costs in capabilities and acquisition analysis of system life-cycle costs.

2) Require energy efficiency as a (Key Performance Parameter) and Milestone B exit criterion for capabilities with significant energy consumption or energy logistics support requirements (LMI, 2007).

A previous thesis demonstrates that naval aviation claims 62 percent of the costs attributable to Navy Major Defense Acquisition Programs most impacted by fuel burden (Corley, 2009). The Rocky Mountain Institute scientific studies stress that the most gallons of fuel could be saved in aircraft, which use 73

percent of DoD fuel, and that savings in aerially refueled aircraft would save the most in delivery costs (Lovins, 2010).

Legislation, directives and policy guidance from a Presidential Executive Order, the 2009 National Defense Authorization Act, Quadrenial Defense Review, defense acqusition directives and OUSD policy makers have set in motion the groundwork for FBCF implementation by October 2011. Wording in these published documents is similar to that in an OSD(AT&L) memo stating it is:

> DoD policy to include fully burdened cost of delivered energy in trade-off analysis conducted for all tactical systems with end items that create a demand for energy and to improve the energy efficiency of those systems, consistent with mission requirements and cost effectiveness. (OUSD(AT&L), 2007)

The objective of this thesis is to advance the framework of estimating FBCF to support analysis of alternatives by the defense acquisition community.

Currently, naval aviation is afforded no DoD formally directed aviation FBCF pilot programs upon which to depend as a guide. The Navy does possess a multitude of useful cost reports and reporting systems but all necessary data to compute FBCF are not centralized in a single database. Naval Air Systems Command (NAVAIR) Cost Department (NAVAIR-4.2.2) developed a FBCF estimate in the fall of 2009 whose preliminary results emphasized the complexity of several calculations, missing data and suggests the need for a consensus on several cost elements (NAVAIR, 2009). Due to the concentration of Navy Major Defense Acquisition Projects overseen by Deputy Assistant Secretary (Air Programs) (DASN[Air]), and recent emphasis on F-22 acquisition cutbacks, tactical aircraft funding and other relatively high cost naval aviation Major Defense Acquisition Programs (MDAP) may be subject to scrutiny.

The first portion of this study computes FBCF using historical prices and FY09 fuel-related costs for the F/A-18E/F. Then we look at OSD's most recent approach to calculating FBCF that necessitates translating future defense planning scenarios into cost parameters to be used in an updated calculator version. The seven cost elements that contribute to a Base Case estimate for F/A-18E/F FBCF are expressed in FY09$. The data used in our estimates are a mix of actual, inferred, and modeled data, and are taken from previous Military Sealift Command, Naval Air Systems Command, and Headquarters, USAF studies. Cost elements inputs to the FBCF calculator generate a $9.59 per gallon mean operations tempo (OPTEMPO) weighted average Assured Delivery Price (ADP), resulting in a mean daily FBCF of $1.9 million a day. The additional cost attributable to the FBCF methods, over an 18-year lifespan, is an increase of $20.9 FY09$B. We conclude the FBCF was 368 percent higher than the reported commodity price of $2.05 per gallon for all F/A-18E/F in FY09. This commodity price multiplier is “a four to five times multiple” compared to the fractional (i.e., one-to-two times multiple) increase in a previous DDG study.

We improve on the 18-year cost estimation with a realistic 33-year F/A-18E/F Operations and Support (O&S) life cycle projecting 3.2B gallons of fuel consumed and a total cost of $30.7 FY09$B. Then we estimate the FBCF for a scenario with six oilers escorted by two destroyers to deliver fuel to four carriers in an operational environment. This exercise highlights the versatility and limitations to the most recent FBCF model that incorporates attrition and the higher costs associated with extra fuel expended by force protection assets.

The study supports literature recommending aviation as a strategic place to focus FBCF analysis to value investment opportunities that increase endurance and decrease O&S costs for air refueling assets. We recommend that to follow guidance and cost estimation models, NAVAIR should emphasize coordination efforts with Office of the Chief of Naval Operations (OPNAV) offices that are responsible for translating Defense Planning Scenarios into cost planning factors usable in FBCF calculators. We note that the complexity of calculating FBCF rises when multiple fuel delivery assets support the platform of study. We provide the cost estimation community with methods to undertake price element calculations and recommend expanded scenario capabilities and documentation updates for the most recent versions of the FBCF Calculator.

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LIST OF ACRONYMS AND ABBREVIATIONS

AOA	Analysis of Alternatives
ACES	Aviation Cost Evaluation System
ADP	Assured Delivery Price
APDF	Aircraft Program Data File
ASN(RDA)	Assistant Secretary of the Navy (Research, Development & Acquisition)
AV-3M	Naval Aviation Maintenance and Material Management System
BOR	Budget Optar Reports
CAIG	Cost Analysis Improvement Group
CAPE	Cost Assessment and Program Evaluation
CE	Cost Element
CER	Cost Estimate Relationship
CNAF	Commander, Naval Air Forces
CVW	Carrier Air Wing
DAG	Defense Acquisition Guidebook
DASN(Air)	Deputy Assistant Secretary (Air Programs)
DDG	Guided Missile Destroyer
DESC	Defense Energy Support Center
DoD	Department of Defense
DoDI	Department of Defense Instruction
DOEPP	Director of Operational Energy Plans and Programs
DON	Department of Navy
DSB	Defense Science Board
FBCF	Fully Burdened Cost of Fuel
FHCR	Flying Hour Cost Reports
FOC	Full Operational Capability
FOCR	Flight Operations Cost Reports
FRS	Fleet Replacement Squadron
GAO	Government Accountability Office
GCV	Ground Combat Vehicle
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HQ USAF	Headquarters, U.S. Air Force
JCIDS	Joint Capabilities Integration and Development Systems

JP/JP-5	Jet Propellant Fuel
JTLV	Joint Light Tactical Vehicle
KPP	Key Performance Parameter
LCC	Life-cycle Cost
LMI	LMI Government Consulting
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MSC	Military Sealift Command
NAS	Naval Air Station
NAVAIR	Naval Air Systems Command
NCCA	Naval Center for Cost Analysis
NDAA	National Defense Authorization Act
NPS	Naval Postgraduate School
OPNAV	Office of the Chief of Naval Operations
OPTEMPO	Operating/Operations Tempo
OUSD(AT&L)	Office of the Under Secretary of Defense for Acquisition,
O&S	Operations and Support
POS	Point of Sale
PPBE	Planning, Programming, Budget and Execution
QDR	Quadrennial Defense Review
RMI	Rocky Mountain Institute
SECDEF	Secretary of Defense
T-AO	Fleet Replenishment Oilers
T-AOE	Fast Combat Support Ship
TMS	Type, Model, and Series
TOC	Total Ownership Cost
USAF	United States Air Force
USN	United States Navy
VAMOSC	Visibility and Management of Operating and Support Costs
WCF	Working Capital Fund

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I. INTRODUCTION

The Defense Acquisition Guidebook (DAG) defines Fully Burdened Cost of Fuel (FBCF) as “The cost of the fuel itself (typically the Defense Energy Support Center (DESC) standard price) plus the apportioned cost of all of the fuel delivery logistics and related force protection required beyond the DESC point of sale (POS) to ensure refueling of the system.” (DAU, 2009) The Duncan Hunter National Defense Authorization Act (NDAA) for Fiscal Year 2009 defined FBCF to mean “the commodity price for fuel plus the total cost of all personnel and assets required to move and, when necessary, protect the fuel from the point at which the fuel is received from the commercial supplier to the point of use.” (110th U.S. Congress, 2008). FBCF is a direct contributor to the Total Ownership Cost (TOC) used in the Analysis of Alternatives (AOA) phase of the Defense Acquisition System process. Furthering the field of FBCF cost estimation into a mature process while continuously improving our understanding of the components that add to the true cost to deliver energy to fuel-demanding platforms will positively influence future defense programs. This knowledge and practice will bring incrementally more robust information to the acquisition decision-making processes.

The analytical method developed by Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD(AT&L)) to estimate FBCF includes seven distinct cost element steps, beginning with a simple commodity price and ending with a complex and variable set of service and platform unique price considerations. The latter element is expected to be the largest in future FBCF calculations, potentially orders of magnitude higher than commodity prices. Independent Cost Estimators, Department of Defense (DoD) Cost Estimators, Program Managers and Financial Managers require workable cost models defined by service, capabilities or platform, and accurate reporting of costs associated with delivering fuel to end users. Recent knowledge gained from applying the OUSD developmental methodology to surface ship platform advanced the FBCF field of study. This thesis will parallel those efforts to estimate and analyze the FBCF applied to a naval aviation fixed wing platform.

A. INFORMATIVE ENERGY RELATED STUDIES AND REPORTS

Numerous studies have informed the guidance and policies created for FBCF. In 2007, an LMI Government Consulting report recommended FBCF concept development action to enable DoD Energy Strategy implementation. More recent reports continue to emphasize a legitimate focus on FBCF as a necessary future Cost Estimation requirement. A September 2009 technical report by the Army Environmental Policy Institute provided commodity resupply casualty factors for fuel-related resupply convoys in Afghanistan and Iraq. This supported MajGen Zilmer's request to measure benefits of DoD's reduced energy dependence by lives rather than dollars saved. This consideration opens the aperture to a breadth of factors that must be considered when burdening the supply chain with fuel demand.

1. 2001 Defense Science Board (DSB) on Fuel Efficiency

An OUSD sponsored study by the Defense Science Board (DSB) in 2001 revealed findings of inefficiencies in DoD business practices. In the report, *More Capable Warfighting Through Reduced Fuel Burden*, DSB recommended investment decisions based on the true cost of delivered fuel and including fuel efficiency in requirements and acquisition processes (DSB, 2001).

2. 2008 DSB Task Force on Energy Strategy

With recommendations from the 2001 DSB study not widely implemented, a February 2008 study by the DSB Task Force recommended accelerated efforts to use FBCF as a factor in all AOA through acquisition tradespace (DSB, 2008).

The board clearly stated the perceived flaw in DoD business process, that the Joint Capabilities Integration and Development Systems (JCIDS) process was uninformed about fuel burden. "The acquisition process does not properly value energy efficiency and hence programs are designed that consume too much of it" (DSB, 2008). It further highlighted concern that, if left to program offices alone, burdened fuel determinations would not be applied evenly.

> The Task Force questions whether program offices have the analytical capability to make this determination, and whether leaving it to individual program offices will result in consistency of approach across programs. (DSB, 2008, p. 30)

3. 2007 LMI on Establishing an Energy Strategy

The Office of Force Transformation and Resources within the Office of the Undersecretary of Defense for Policy requested LMI Government Consulting to develop an approach to establish a DoD energy strategy. Their research resulted in three major disconnects between DoD's published energy strategy and the current practices involving energy consumption practices. Specifically, "DoD's operational concepts seek greater mobility, persistence, and agility for our forces. But, the energy logistics requirements of these forces limit our ability to realize these concepts" (LMI Government Consulting, 2007). Their recommendations suggest the department should focus on three areas that would have the greatest impact on addressing disconnects between strategy and practices. One of these was the area of greatest fuel use by our aviation forces. Their support for this recommendation hinges on observation of increasing reported fuel costs, which had doubled since September 11, 2001.

> Because the military has relied on air operations to sustain and complement ground forces and because the defense strategies demand increased mobility, agility, and sustainment, DoD can expect continued high energy usage and higher energy costs. This consumption and price trend clearly points to an area in which a comprehensive strategy is warranted. (LMI, 2007, p. A-2)

LMI proposed a vision statement to enable senior leaders in the department to attain a meaningful energy strategy.

> DoD will be the nation's leader in the effective use of energy, significantly reducing DoD's dependence on traditional fuels and enhancing operational primacy through reduced logistics support requirements. (LMI, 2007, p. vi)

The LMI message further provided suggestions for implementation steps applied to strategic planning, analytic agenda, joint concept and joint capability development, acquisition, and Planning, Programming, Budget and Execution (PPBE) processes. "Incorporate energy considerations (energy use and energy logistics support requirements) in all future concept development, capability development, and acquisition actions." This implementation step involved two key supporting actions indicating the strategic value of FBCF concepts: (1) Implement the use of fully burdened fuel costs in capabilities and acquisition analysis of system life-cycle costs. (2) Require energy efficiency as a Key Performance Parameter (KPP) and Milestone B exit criterion for those capabilities with significant energy consumption or energy logistics support requirements (LMI Government Consulting, 2007).

4. 2009 NPS Thesis Estimating FBCF for DDG-51

In a Naval Postgraduate School (NPS) thesis published September 2009, Corley wrote of the 25 most fuel burdened Navy Major Defense Acquisition Programs (MDAP). His analysis shows that Naval Aviation claims 62 percent of the costs attributable to programs most impacted by fuel burden (Corley, 2009). The application of the seven-step methodology to a DDG-51 fleet scenario necessitated several assumptions where data was unavailable.

5. 2009 Army Environmental Policy Institute

A September 2009 technical report by the Army Environmental Policy Institute provided commodity resupply casualty factors for fuel-related resupply convoys in Afghanistan and Iraq. This supports MajGen Zilmer's request to measure benefits of DoD's reduced energy dependence by lives rather than dollars saved. This consideration opens the aperture to a breadth of factors that DoD must consider when burdening the supply chain with fuel demand.

6. DoD's Energy Challenge Creates Strategic Opportunity

In 2010, Joint Forces Quarterly published Rocky Mountain Institute (RMI) Chairman and Chief Scientist Amory Lovins' paper concerning the opportunities available to DoD to reverse trends of energy inefficiency and poor design. He reports 2005 data indicating that 73 percent of DoD fuel is used by aviation assets, with Navy aircraft consuming roughly 12 percent of the total DoD liquid petroleum consumed: over 600 million gallons. The article describes DoD energy logistics as a "soft underbelly" vulnerable to future attacks not realistically considered or modeled in war-gaming scenarios, and also as a resource liability, estimating that "logistics uses roughly half the Department's personnel and a third of its budget" (Lovins, 2010).

Mr. Lovins criticizes the current DoD guidance as incomplete, improperly using book depreciation, under-accounting for personnel costs, attrition and lift requirements. "FBCF should count all assets and activities—at their end-to-end, life cycle, fully burdened total cost of ownership—that will no longer be needed, or can be realigned, if a given gallon need no longer be delivered." Even so, he is optimistic that even at conservative levels of (one to two orders of magnitude), leadership use of these metrics will result in strategic opportunities to create innovative capability solutions for the DoD (Lovins, 2010).

Lovins' article is encouraging, however, in stating that if DoD pursues energy efficiency technologies, there is an "estimated potential to cut total DOD mobility-fuel requirements by about two-thirds, perhaps even three-fourths." The most robust cost saving targets include:

- The most gallons can be saved in aircraft, which use 73 percent of DoD fuel. Saving 35 percent of aircraft fuel would free up as much fuel as all DoD land and maritime vehicles plus facilities use.
- Savings in aerially refueled aircraft and forward-deployed ground forces save the most delivery cost and thus realignable support assets (Lovins, 2010).

RMI supports the DSB finding that “DOD's energy problems [are] sufficiently critical to add two new strategic vectors” to complement the four historic ones: “speed, stealth, precision and networking.” He continues with evidence pointing to endurance as a strategic vector capability that would make a big difference in military operations and airborne refueling cost savings (Lovins, 2010).

B. APPLICABLE GUIDANCE FOR DOD

Energy management guidance to and from DoD clearly has been gaining intensity. Executive Order 13423, dated January 26, 2007, states that Federal agencies must “conduct missions in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner.” In a memo dated April 10, 2007, USD(AT&L) codified “DoD policy to include fully burdened cost of delivered energy in trade-off analysis conducted for all tactical systems with end items that create a demand for energy and to improve the energy efficiency of those systems, consistent with mission requirements and cost effectiveness” (OSD(AT&L), 2007). Department of Defense Instruction DoDI 5000.02, Operation of the Defense Acquisition System, was updated to direct that “the fully burdened cost of delivered energy shall be used in trade-off analysis for all DoD tactical systems with end items that create a demand for energy” (OUSD(AT&L), 2008). This, in effect, creates a direct input requirement to the AoA phase required for Milestone Decision point B. The 2009 NDAA directs the Secretary of Defense to “require life-cycle cost analysis for new capabilities include the fully burdened cost of fuel during analysis of alternatives and evaluation of alternatives and acquisition program design trades.” Implementation is directed no later than October 14, 2011, three years after the enactment of Fiscal Year 2009 NDAA, with a progress report to Congress due one year prior (110th U.S. Congress, 2008).

1. Presidential Executive Order 13423

On January 24, 2007, President Bush issued Presidential Order 13423. This document announced, “policy of the United States that Federal agencies conduct missions in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner.” This high-level document outlines, at the most senior level, objectives intended to maximize the economic efficiency of energy use, applying to DoD as a federal agency (The White House, 2007).

2. 2009 NDAA and Congressional Interests

Congress enacted the 2009 Duncan Hunter National Defense Authorization Act in October 2008. This congressional act authorizes funds budgeted for DoD weapons systems acquisition. For the first time, the act prescribed conditions under which fuel logistics costs must be considered during the acquisition process.

The 2009 NDAA directs the Secretary of Defense to “require life-cycle cost analysis for new capabilities include the fully burdened cost of fuel during analysis of alternatives and evaluation of alternatives and acquisition program design trades.” Section 332 prescribes a definition of FBCF and requires the Secretary of Defense (SECDEF) implementation progress and compliance notifications. The act gave six-month, two-year, and three-year deadlines to develop an implementation plan, provide a progress report, and implement 2009 NDAA requirements, respectively (110th U.S. Congress, 2008). Table 1 summarizes the SECDEF implementation plan creation, progress report, and final implementation requirement deadlines legislated according to the 2009 NDAA enacted October 2008.

2009 NDAA Legislated Implementation Deadline Summary		
Event/Requirement	Lead Time	Deadline
2009 NDAA Enacted		14-Oct-08
Prepare Implementation Plan	180 days	14-Apr-09
Provide Progress Report	2 years	14-Oct-10
Implement NDAA Requirement	3 years	14-Oct-11
Source: 2009 Duncan Hunter National Defense Authorization Act		

Table 1. 2009 NDAA FBCF Implementation Deadline Summary

As reported in an October 2009 article from TheHill.com, Congressional attention peaked when DoD estimated that fuel delivered for operations in Afghanistan exceeds $400 per gallon. The writer claimed figures like these will escalate the debate in Congress over demand for accurate accounting of operations costs, such as fuel, used in contingency operation areas (Tiron, 2009).

3. DoD Defense Acquisition Guidance Guidebook

DoDI 5000.02 Operation of the Defense Acquisition System was updated to include guidance for FBCF. The 2008 update directs that “the fully burdened cost of delivered energy shall be used in trade-off analysis for all DoD tactical systems with end items that create a demand for energy” (OUSD(AT&L), 2008). This, in effect, creates a specified component of input requirement to the AOA phase, a critical prerequisite for Milestone Decision points. The Milestone Decision Authority (MDA) has the responsibility to assess the extent to which programs considered efficiency improvements for tactical systems that create a demand for energy (OUSD(AT&L), 2008). This provides a measure of forcing function, embedding its use in calculations required during AoA. A program that neglects it, by definition, risks stalled progression through the formal hurdles of Milestone Decision Authority review.

4. Quadrennial Defense Review

The Quadrennial Defense Review (QDR) Report, published February 2010, outlines DoD's priorities in the congressionally mandated four-year plan. The document is designed to represent the reshaping of the U.S. Military by guiding the balance between meeting today's wartime needs and planning for the capability needs of tomorrow. In one of the six major sections of the report, DoD focuses on the objective *Reforming How We Do Business*. Multiple subsections address challenges and appropriate responses in DoD's way forward supporting energy strategy. In "*Ensuring integrity in the acquisition process,*" DoD highlights the importance that "major programs are subjected to early and clear definition of approved requirements based on a rigorous assessment of alternatives." In "*Crafting a Strategic Approach to Climate and Energy,*" DoD addresses energy security—the ability to protect and deliver sufficient energy to meet operational needs. "DoD must incorporate geostrategic and operational energy considerations into force planning, requirements development, and acquisition processes." The QDR follows with a clear message of intended compliance, stating DoD "will fully implement the statutory requirement for the energy efficiency Key Performance Parameters and fully burdened cost of fuel set forth in the 2009 NDAA" (Department of Defense, 2010).

5. OUSD(AT&L) Guidance Role

OUSD(AT&L) maintains responsibility to implement policy and oversee the DoD Acquisition process. The Deputy Secretary concurred with the Institute of Defense Analyses, DSB Task Force, Energy and Security Task Force conclusions that a force less dependent on a logistics tail is a more flexible force, and that the acquisition process undervalues energy efficient technology. Fulfilling the office policy and oversight duties in a memo dated April 10, 2007, the USD(AT&L) codified a FBCF estimation requirement with policy language. "Effectively immediately, it is DoD policy to include fully burdened cost of delivered energy in trade-off analysis conducted for all tactical systems with end items that create a demand for energy and to improve the energy efficiency of those systems, consistent with mission requirements and cost effectiveness" (OUSD(AT&L), 2007). Additionally, the memo announced three pilot program initiatives to engineer the business practices supporting policy implementation. One of these three was aviation related: the Next-Generation Long-Range Strike concept decision (OUSD(AT&L), 2007).

In March 2008, testifying before the House Committee on Armed Services Readiness Subcommittee on behalf of the Deputy Under Secretary of Defense (Acquisition and Technology), Mr. Chris DiPetto outlined the office's approach to DoD energy risks and energy governance. He recounted the DAWG-directed examination of the DoD capability development process to identify ways to mitigate how our forces' fuel demands threaten the logistics tail. He emphasized the two main purposes for determining FBCF are to (1) gain insights for decision makers on the risks created by DoD's huge fuel demand, and (2) "open up science and technology … and acquisition tradespace with properly valued financial costs of delivering fuel to the operator." In an April 2007 policy memo, OUSD(AT&L) had directed three pilot acquisition programs, one of which was the Air Force's next generation long range strike program (Dipetto, 2008). Nearly two years past, the immediate focus on FBCF [was] to mature the methodology, add it to relevant DoD guidance, and seek applications in earlier phases of DoD capability development processes (DiPetto, 2008).

C. THESIS OBJECTIVES (BENEFIT OF THE STUDY)

Implementation of the FBCF concept has been slow. The Government Accountability Office (GAO) has reported that DoD efforts to implement fuel cost saving initiatives have been limited (GAO, 2009). <u>The objective of this thesis is to advance the framework of estimating FBCF to support analysis of alternatives by the defense acquisition community.</u> To meet the congressionally mandated implementation timeline, continued incremental improvement to the OUSD(AT&L) model must be achieved. Closer observation of the cost model applied to a range of scenarios for multiple platform types is required. This study will continue that estimation effort for a substantial portion of the burdened cost of fuel for one naval aviation platform. This study can be considered a base case from which to begin future estimates for fixed wing tactical aircraft involving a growing complexity of operational scenarios.

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II. STATUS OF FBCF FOR NAVAL AVIATION

This chapter contains an assessment of naval aviation readiness to comply with FBCF mandates and guidance through four focus areas. The 2007 AT&L memo brought promise, but not assurance, of an aviation related FBCF pilot study. Current naval aviation related cost reports do provide the basis for some required FBCF analysis. To date, Naval Air Systems Command (NAVAIR) cost estimators have put forth a significant, although not yet complete, effort to estimate FBCF. The Department of the Navy should be mindful of the future implications that inherent high relative acquisition dollar figures, legislation, and DoD guidance for FBCF analysis will have on naval aviation.

A. STATUS OF FBCF PILOT PROGRAMS FOR AVIATION

Of the three pilot programs nominated by OSD(AT&L) and identified in the April, 2007 memo, one was aviation related. At the time of this research, the pilot program for the Next-Generation Long-Range Strike aircraft remains delayed. This leaves naval aviation with no DoD formally directed studies with which to compare FBCF cost estimation methods and standards.

B. DATA REPORTS FOR NAVY AVIATION COST REPORTING

The Aviation Cost Evaluation System (ACES) is a naval aviation database envisioned to track all aviation related costs and designed to provide flying hour program visibility down to the organizational level. ACES is advertised to be the only source to respond to Office of the Chief of Naval Operations (OPNAV) regarding costs and cost per hour (price) information. Input sources include Budget Optar Reports (BOR), Aircraft Program Data File (APDF) schedules, Flying Hour Cost Reports (FHCR), Flight Operations Cost Reports (FOCR), and Analysis of Navy Flying Hour Program (OP-20) budgeting reports. Regular outputs include “Certified” FHCRs and FOCRs (CACI Dynamic Systems Inc., 2008)

The BOR comes from squadrons on a monthly basis, providing number of aircraft assigned, flight hours flown, gallons of fuel consumed and other associated squadron costs. The FHCR provides annual costs and cost per hour for all aviation related cost types, including fuel, summarized by aircraft Type, Model, and Series (TMS) and totaled by Navy and Marine tactical air, support, strategic or Fleet Replacement Squadron (FRS) aircraft. The FOCR summarizes similar data to generate cost per gallon figures often grouped by Carrier Air Wing (CVW) separated by TMS and squadron. OP-20 reports summarize fiscal year FHCR information to serve as budgeting guidance input for subsequent years. Certified FOCR and FHCR data is useful to determine actual fuel commodity prices, fuel demand and proportion of fuel each platform consumes in the period of the report.

The Naval Aviation Maintenance and Material Management (AV-3M) System provides data from which information such as deckplate reports are generated. This system produces information reports that provide management tools for the efficient and economical management of maintenance organizations (NAVAIR, 2010). Deckplate reports include flight purpose codes and flight hours. The Deckplate DP-0014 reports by squadron on the organization monthly operations code and flight hours. The Deckplate DP-0041 reports provided details for individual sorties sortable by TMS. Analysis of these reports provides information on operating environment and the mission assignments useful in cost allocation.

C. HOW NAVAIR CALCULATES FUEL COMPONENT OF TOC

The NAVAIR Cost Department (NAVAIR-4.2.2) developed a FBCF estimate in the fall of 2009. The study was naval aviation platform all-inclusive, based on support from Fleet Replenishment Oilers (T-AO) and multiple air refueling platforms, including estimates for the first four cost elements. Their data sources include DESC Fuel Cost and Delivery Reports, Deckplate Reports (DP-4001 and DP-0014), Visibility and Management of Operating and Support

Costs (VAMOSC), Naval Air Training and Operating Procedures Standardization (NATOPS) Manuals, Carrier Personnel Manning documents, Aircraft Inventory Readiness and Reporting System (AIRRS) reports, Patuxent River Fuel Farm contracts, and Military Sealift Command (MSC) financial data (NAVAIR, 2009).

NAVAIR 4.2.2 conducted extensive analysis to estimate the depreciation on each naval refueling tanker platform using VAMOSC cost data, usage, lifespan, and performance with analysis dedicated to determining to what extent F/A-18E/F assets dedicate mission flight hours to airborne fuel delivery. This drives the contribution of depreciation attributable to the tanker role. The study estimated indirect costs of carrier refueling labor based on the salary for Aviation Boatswain's Mate—Fuels (ABF) personnel divided by total estimated fuel delivered to carrier aircraft.

The NAVAIR 4.2.2 analyst concludes that additional data are required to refine their initial estimates. "To develop very precise cost per tanker platform per gallon for Operations and Support (O&S) cost and depreciation [we] need source to identify total gallons delivered via naval assets and actual flight usage for Air Force tankers refueling USN aircraft." The preliminary results report emphasized the complexity of several calculations, missing data and the analyst recommendations for consensus on the final three cost elements (NAVAIR, 2009). This thesis leverages the detailed research by NAVAIR 4.2.2 for several cost elements including O&S costs for T-AO refueling operations and F/A-18E/F O&S and depreciation costs.

D. FBCF FUTURE IMPLICATIONS FOR FIXED WING AIRCRAFT

1. MDAP Dollars Concentration in Naval Air

The Corley DDG-51 FBCF thesis evaluated the MDAPs current as of the December 9, 2008, Assistant Secretary of the Navy (Research, Development & Acquisition) ASN(RDA) report. The study illustrated the relative size of Department of Navy (DON) acquisition programs most impacted by energy and fuel-related burdens. It concludes that Deputy Assistant Secretary (Air

Programs) (DASN[Air]), programs account for over 56 percent of all MDAP Research Development Test and Evaluation and procurement costs (Corley, 2009).

2. Acquisition Reform and Impending MDA Decisions

The Weapon Systems Acquisition Reform Act of 2009 places emphasis on eliminating waste and inefficiency of overspending our defense funding on expensive capabilities not required. With recent emphasis on F-22 acquisition cutbacks, tactical aircraft funding and other relatively high cost aviation MDAPs will be subject to similar scrutiny. The MDAPs closest to Major Decision Authority milestone decision points with FBCF implications are the Army's armored fighting vehicle replacement Ground Combat Vehicle (GCV), and the High-Mobility Multipurpose Wheeled Vehicle (HMMWV) replacement Joint Light Tactical Vehicle (JTLV) (Cotman, 2010).

III. METHODOLOGY

This study used both OUSD(AT&L) FBCF calculator version two and version seven, henceforth referred to as V2 and V7. The spreadsheets follow DAG methodology and provide a mathematical process to calculate FBCF using Excel spreadsheets employing Monte Carlo simulations. Corley's thesis used V2 to generate a "Base Case Estimate" for an existing surface ship platform. This thesis first paralleled the DDG-51 data analysis for a fixed wing naval aviation platform. In collaboration with the Naval Center for Cost Analysis (NCCA), NAVAIR, and Headquarters, U.S. Air Force (HQ USAF), we applied historical costs, valid cost estimation practices, and leveraged recent aviation FBCF studies to estimate the fuel demand component of TOC calculations supporting the AoA process. The output is an operations tempo (OPTEMPO) weighted dollars per gallon subjected to sensitivity analysis, and compared to the DDG-51 study results. Next, we use a notional operational scenario to demonstrate V7 calculator utility. We collected data, followed OUSD FBCF estimation methodology guided by OSD Cost Analysis Improvement Group (OSD(CAIG)) cost estimating principles, noting when methods differ from DDG-51 analysis.

A. DATA COLLECTION

As reviewed in the Chapter I, fuel is a major contributor to O&S costs. These costs are tracked for naval aviation assets in flying hour program reports submitted by squadrons through to higher commands. Much of the data from these reports is automatically but sometimes manually input into cost reporting systems such as VAMOSC and ACES, and AV-3M. We obtained VAMOSC information primarily by online data requests from www.navyvamosc.mil, supplemented with user account queries. Commander, Naval Air Forces (CNAF) personnel supplied ACES data reports in the form of FOCR and BOR, and FHCR. We used AV-3M Deckplate reports retrievable from NAVAIR Logistics

Web page www.navair.navy.mil/logistics. Because access is limited to password-protected accounts, we used the Deckplate reports provided by NAVAIR 4.2.2 personnel.

B. OUSD FBCF METHODOLOGY

This section will address the seven step cost element calculation methodology as outlined in the DAG and amplified in the OSD(AT&L) calculator description. OSD(AT&L) published general guidelines for computing FBCF in chapter three of the DAG, entitled “Methodological Guidance for Analyses of Alternatives and Acquisition Tradespace Analysis.” OSD introduces motivation for developing and utilizing the methodology as a tool to counter the following chain of negative effects: Inefficient energy usage increasing the logistics tail, which increases logistics footprint, unnecessarily increasing risk as the department shifts operational personnel and assets to logistics, simultaneously reducing funding available for operations and increasing logistics funding (Defense Acquisition University, 2009). See Appendix A for Corley’s summary description of the seven cost elements.

C. OSD(CAIG) COST ESTIMATION METHODS

To the extent possible, this study complied with the OSD(CAIG) Cost-Estimation Guide, published in October 2007, which provides guidance to develop estimates of O&S costs as directed in 5000 series DoD instructions (OSD(CAIG), 2007). We modeled data using forecasting techniques, created Cost Estimation Relationships (CER), and used data inference where feasible. We built a time-phased O&S Display presentation as described in the guide section detailing OSD(CAIG) review procedures. “The presentation will include a display of time-phased O&S costs by major time periods (such as deployment, steady-state [Full Operational Capability (FOC)], and phase-out periods), as well as a display of annual steady-state recurring O&S costs” (OSD(CAIG), 2007).

D. MODIFYING INPUTS FOR NAVAL AVIATION PLATFORM

This section addresses the different approach this study took from the DDG-51 analysis and the changes to the OSD FBCF calculator since then. We add complexity to the DDG-51 study and observe complications that arise when considering multiple fuel delivery assets. Additionally, we found it necessary to expand beyond the VAMOSC available data source to represent various costs and find metrics upon which to base our cost allocations. Since the DDG-51 study in Corley's thesis, OSD has transformed the calculator to address more DAG methodology requirements. V7 incorporated costs of fuel lost and asset attrition planning, accounting for the value of escort vehicles and aircraft. Versions of the calculator modified for air refueling operations bring capability to measure output in units of dollars per hour as well as dollars per day.

E. THESIS APPROACH TO CLASSIFIED DEFENSE PLANNING SCENARIOS AND V7 CALCULATIONS

The first portion of this study evaluates FBCF primarily using historical prices and fuel demand in the year FY09. In the latter part of this estimation study, we look at the latest approach to calculating FBCF, placing particular emphasis on applying metrics derived in the context of an operational scenario. Due to the unclassified nature of this study, we did not use classified Defense Planning Scenarios. This study uses a mix of historical data and notional planning parameters generated from a simple unclassified notional scenario supporting Navy tactical air assets. The OSD FBCF Calculator V7 (FBCF Calculator v7.0.xls) primarily computes three significant operational cost elements. The other cost elements calculations are guided by much less direct methods.

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IV. COST ANALYSIS OF AN FBCF ESTIMATE

This chapter represents the details of the cost analysis for FBCF associated with the F/A-18E/F. This is not an economic analysis. It does not compare the relative merits of alternative assets or distinguish between alternative fuel delivery or security technologies, processes, or procedures. It presents the costs associated with fuel and associated burdens observed to fulfill logistical support for operational requirements. To meet thesis objectives, this section directly parallels Corley's analysis of the DDG-51 surface ship fleet. We follow a cost analysis process with the intention to compare a FBCF estimate with Corley's results. We start with assumptions, calculate Cost Element (*CE*) components mirroring the seven-step DAG process, perform sensitivity analysis and report the FBCF results. Next, we examine impacts on life-cycle cost (LCC), compare Assured Delivery Price (ADP) to price of non-delivered fuel at commodity and standard prices and contrast results with the FBCF factors calculated in the DDG-51 study. Next, we calculate LCC using a more realistic O&S aircraft deployment schedule and examine a notional scenario with a recent developmental model calculator version.

A. BASE CASE ASSUMPTIONS

We use the "investigational model" to develop a Base Case estimate of the FBCF for the F/A-18E/F aircraft. Using FY09 VAMOSC, DESC, NAVAIR, HQ USAF, MSC and other data outlined in paragraph III.A., we use a combination of cost estimation methods including actual cost and analogy, and apply inferential data to calculate the Base Case estimates. The assumptions necessary to use these data consistent with accepted cost estimation methods are below. In parenthesis are references to the primary cost element calculations to which the assumptions apply.

- The 358 active F/A-18E/F assets on which FY09 Jet Propellant Fuel (JP) consumption data were reported in VAMOSC constitute the F/A-18E/F fleet (OP_1, SP_1).
- The Base Case computations consider only JP consumption data and O&S costs reported to VAMOSC in 2009 for commodity fuel price (OP_1, SP_1).
- Use JP generically to represent both JP-8 and JP-5 fuels whose standard price varies insignificantly by $0.02 per gallon (all).
- Inflation indices generated by Joint Inflation Calculator, version January 2010, will use DoD wide values where more specific appropriations categories do not apply (OP_2).
- “Steady-state” activity is practically defined in this study using Deckplate Report (DP-0014) flight purpose codes beginning with 1, 3, A, and C. Conversely, purpose code 2 or B. defines “Operational” activity (OP_2, SP_2, OP_3, and SP_3).
- Primary fuel delivery vehicles have use ratios that are similar during steady-state non-deployed shipboard operations to those during deployed shipboard operations (SP_2).
- Lifespan of an F/A-18E/F asset is 18 years with a 10 percent salvage value (NAVAIR, 2009) (OP_3).
- Lifespan of a T-AO asset is 40 years (OP_3).
- All F/A-18E/F Aircraft operate from and receive infrastructure support from two primary naval air stations located at Naval Air Station (NAS) Oceana and NAS Lemoore. Other locations include NAS Fallon, and NAF Atsugi, Japan NAS China Lake, and NAS Patuxent River (SP_4).
- Infrastructure direct costs to indirect (labor) costs onboard carriers are similar to those of NAS fuel division costs (OP_4).
- Land based operational costs are negligible compared to shipboard operations for F/A-18E/F (OP_5)
- All costs, measurements and values represent FY09 dollars or are inflated to account for FY differences.

Terminology clarifications and updates must be applied to differences in the OSD(AT&L) model calculator V2 and V7. Recent guidance changes and terminology updates are continuous and tend to be used interchangeably in the literature and in this study (Cotman, 2010).

- The updated (V7) OSD model substitutes the term “Cost Elements” with “Price Elements.”
- The subscripted term “Fully Burdened Cost of Fuel, Supplied” ($FBCF_S$) is interchangeable with “Assured Delivery Price.”
- As of April 2010, substitute the term “foundational activities” for steady-state operations.

B. BASE CASE ESTIMATE

The paragraphs in this section follow in order with DAG methodology and the OSD(AT&L) calculator. The seven cost elements that contribute to a Base Case estimate for F/A-18E/F FBCF are expressed in FY09$ per gallon. The data used in our estimates are a mix of actual, inferred, and modeled data, and are taken from previous MSC, NAVAIR and HQ USAF studies. Although computation values maintain multiple decimal places to minimize rounding errors, price estimates are displayed rounded to the nearest penny.

1. *Commodity Cost of Fuel ($/gal):* The DESC standard price changed four times throughout FY09. The average of the five prices for JP-5 was $2.42 per gallon ranging from $1.46 to $4.10 (DESC, 2009). When considering the time weighted values, the price averaged $2.20 per gallon due to more days subject to lower standard prices. This estimate uses neither the numerical average ($2.42) nor daily price average ($2.20), but actual cost and fuel consumption totals for the F/A-18E/F fleet reported in VAMOSC. The average JP cost per F/A-18E/F was $880,219 for 358 total aircraft consuming a total of 153.8 million gallons. Total fuel costs were over $135 million and $179 million for over 66 million gallons and over 87 million gallons consumed by F/A-18E and F/A-18F respectively. Equation (IV.1) displays the calculation for average commodity Price of Fuel (OP_1 and SP_1) for F/A-18E/F JP as $2.05 per gallon. Table 2 itemizes inputs to this calculation.

$$OP1, SP1 : CommPriceOfFuel(\$/gal) = \frac{TotalJPCosts(\$)}{TotalGallonsConsumedNavyE\,\&\,F} = \frac{\$135,781,749 + \$179,336,675}{66,271,464 + 87,529,512(gal)} = \$2.05/gal \quad \text{(IV.1)}$$

2009 F/A-18 E/F JP Fuel Consumption Data	2009	
F/A-18E	Constant $FY09	Count
1.2.5.1 Fuel Costs- Navy	$119,238,860	
4.1.2.5.1 FRS Fuel Costs- Navy	$16,542,889	
Total Fuel Cost for F/A-18E	$135,781,749	
A5.1.1 Regular Barrels of Fuel Consumed - Navy		1,385,650
A5.2.1 FRS Barrels of Fuel Consumed - Navy		192,242
Total Barrels of Fuel Consumed - Navy E		1,577,892
Total Gallons of Fuel Consumed - Navy E		66,271,464
F/A-18F	Constant $FY09	Count
1.2.5.1 Fuel Costs- Navy	$127,521,206	
4.1.2.5.1 FRS Fuel Costs- Navy	$51,815,469	
Total Fuel Cost for F/A-18F	$179,336,675	
A5.1.1 Regular Barrels of Fuel Consumed - Navy		1,481,899
A5.2.1 FRS Barrels of Fuel Consumed - Navy		602,137
Total Barrels of Fuel Consumed - Navy F		2,084,036
Total Gallons of Fuel Consumed - Navy F		87,529,512
Average JP Cost per gal (F/A-18E/F)	$2.05	

Table 2. FY09 F/A-18E/F JP consumption cost data

Cost reporting on 158 F/A-18E and 200 F/A-18F aircraft from FY09 VAMOSC data. The cost element breakdown structure defines element 1.2.5.1 Fuel Costs—Navy as the cost of aviation propulsion fuel purchased by the Navy to support flight operations of Navy and Marine Corps regular [CVW assigned] aircraft. 4.1.2.5.1 FRS Fuel Costs—Navy is the fuel portion of FRS Operational Costs (NCCA, 2009).

2. *Primary Fuel Delivery Asset O&S Cost ($/gal):* The cost of fuel per gallon differs for the F/A-18E/F during operational (OP_2) and steady-state (SP_2) conditions. We first consider OP_2 as a weighted function of three separate delivery vehicles in the deployed shipboard environment. SP_2 is determined as a weighted function of steady-state land operations and steady-state non-deployed shipboard operations.

Operational delivery vehicle asset O&S calculation is complicated due to consideration of several required primary delivery assets. This estimate uses a weighted function of T-AO/E fleet replenishment oiler and T-AOE fast combat support fleet, USAF KC air refueling fleet and the organic USN tanker (F/A-18E/F only) O&S costs. MSC financial data are the source for T-AO and T-AOE total delivery costs and JP gallons delivered to Navy carriers during FY08. Additionally, the NAVAIR Cost Estimation Division (NAVAIR-4.2.2) conducted detailed analysis of FY08 air refueling platform costs including the F/A-18E/F. We inflate FY08 cost estimates to FY09 dollars. NAVAIR used MSC financial data placing JP-5 delivery on a per gallon basis at the inflation-adjusted price of $1.00 for FY09 (Appendix B, Figure 9). A HQ USAF FBCF study estimated KC-10A delivery of JP fuel at $21.47 per gallon in FY08. NAVAIR estimated F/A-18E/F delivery of JP-5 fuel at $11.90 per gallon in FY08 (see Appendix B, Figure 10 and Figure 11). Table 3 summarizes operational gallons in millions delivered, which we use as the basis for weighting O&S costs. Equation (IV.2) displays the calculation for weighted average of operational delivery asset O&S costs (OP_2) with FY08 dollars inflated to FY09.

$$OP2: DeliveryAssetO\&S.Operational(\$/gal)=$$

$$\frac{TAO(\$/gal)*TAOgal}{Totalgal(gal)}+\frac{KC(\$/gal)*KCgal}{Totalgal(gal)}+\frac{FA18EF(\$/gal)*EFgal}{Totalgal(gal)}= \quad \text{(IV.2)}$$

$$\frac{\$1.00*140.8M}{337.2(Mgal)}+\frac{\$21.79*227.7M}{337.2(Mgal)}+\frac{\$12.08*8.7M}{337.2(Mgal)}=\$13.80/gal$$

We also note that the air refueling assets contribute 97 percent of the costs applied to this price element as determined in equation (IV.3).

$$\frac{AirRefuelingCosts}{TotalRefuelingCosts} = \frac{\$21.79*227.7+\$12.08*8.7}{\$1.00*140.8+21.79*227.7+\$12.08*8.7} = 97.3\% \quad \text{(IV.3)}$$

As categorized in Appendix B, Table 15, steady-state operations occur as land operations or non-deployed shipboard operations. At NAS locations, steady-state land operations fuel delivery occurs in two ways. Fuel flows through pipes to "hot-pits" owned by DESC whose property is recapitalized through standard pricing within the Working Capital Fund (WCF), or through refueling trucks leased and operated by NAS fuel divisions. We do not account for truck-refueling costs here, but as direct O&S costs (SP_4) in paragraph four. Therefore, to avoid double counting costs, in this section we consider land operations fuel delivery vehicle O&S price as $0 per gallon. Steady-state (non-deployed) shipboard operations fuel delivery vehicles include T-AO/E, USAF KC, and F/A-18E/F. For the Base Case, we assume the use ratio of fuel delivery assets is the same as in deployed shipboard operations. Appendix B, Table 15 provides the percentage of steady-state ship operations (20.87 percent) versus land operations (79.13 percent) summarized in Table 3Table 3. . Equation (IV.4) shows the calculation for weighted average of steady-state delivery asset O&S costs (SP_2).

$$\begin{gathered} SP2: DeliveryAssetO\,\&\,S.SteadyState(\$/gal) = \\ OP2*\%ShipOps.SteadyState + LandOps(\$/gal)*\%LandOps.SteadyState = \\ \$13.80/gal*0.2087+\$0/gal*0.7913 = \$2.88/gal \end{gathered} \quad \text{(IV.4)}$$

OP_2, SP_2, OP_3, SP_3 Weighted Average Input Summary Table					
OPTEMPO Category	Ship Ops				Land Ops
Steady State	20.87%				79.13%
Operational	Total	T-AO/E	KC Tanker	F/A-18E/F	
gallons (M)	377.2	140.8	227.7	8.7	
Source		FY08 MSC	FY08 USAF	FY08 NAVAIR	
Source (Steady-State ops): FY08 DP-0014					
Sources: MSC Financial Data2008 , USAF FBCF Study FY08, NAVAIR FBCF Study FY08					

Table 3. Weighted average inputs for primary fuel delivery asset O&S (*OP_2, SP_2*) and depreciation (*OP_3, SP_3*) calculations

Table 3 summarizes Appendix B, Table 15 calculations and data from Figure 9, Figure 10, and Figure 11 for weighted average of steady-state percentages based on total USN flight hours, and operational weights based by total gallons of fuel delivered by the Fuel Delivery Assets (T-AO/E, USAF KC, and F/A-18E/F). Land Operations account for 79.13 percent of steady-state operations; KC tanking gallons account for 227.7 million of all 377.2 million JP fuel gallons delivered.

3. *Depreciation Cost of Primary Fuel Delivery Asset ($/gal):* In this section, we estimate depreciation costs for the primary fuel delivery assets. Depreciation is calculated on a per gallon delivered basis. As in O&S (*OP_2, SP_2*) calculations in paragraph two, we weight the depreciations of the three primary delivery vehicles by the percentage of fuel they deliver. The following depreciation estimates are inflation adjusted from FY08 dollar figures. Table 4 displays the calculations Corley used to estimate T-AO depreciation at $0.50 per gallon. HQ USAF calculated depreciation of a representative (KC-10A) tanker asset at $0.24 per gallon shown in Table 5. NAVAIR analysis of the F/A-18E/F $11.09 depreciation cost per gallon is included in Appendix B, Figure 11.

	(12) T-AO Assets
Procurement Cost (ea) 1998	$ 600,000,000.00
Procurement Total 1998	$ 7,200,000,000.00
Inflation Factor 1998-2008	1.2043
Procurement Total 2008	$ 8,670,960,000.00
Expected Lifetime per T-AO (yrs)	40
T-AO Fleet Annual Depreciation	$ 216,774,000.00
Fleet DFM Consumption (gal)	429,885,189
Depreciation of T-AO Fleet ($/gal)	$ 0.50

Table 4. Cost of depreciation of MSC T-AO oilers (From Corley, 2009, p.25)

STEP 3: Depreciation Cost of Primary Fuel Delivery Assets	
	KC-10A
Gross Book Value	$1,619,941,347
Average Useful Life	30
Annual Straight Line Depreciation	$53,998,045
Aviation Fuel Delivered (gal)	227,741,894
Depreciation Per Gallon	**$0.24**
Source: CAMS-ME - Capital Asset Management System	

Table 5. HQ USAF cost of depreciation of USAF KC tanker (From HQ USAF, 2009)

Equation (IV.5) displays the calculation for the weighted average of operational delivery asset depreciation costs (*OP_3*) with FY08 dollars inflated to FY09. The average price of depreciation for delivered fuel in the operational OPTEMPO category is $0.59 per gallon.

$$OP3: DeliveryAssetDepreciation.Operational(\$/gal) =$$

$$\frac{TAODep\$/gal*TAOgal}{Totalgal} + \frac{KCDep\$/gal*KCgal}{Totalgal} + \frac{E/FDep\$/gal*E/Fgal}{Totalgal} = \quad \text{(IV.5)}$$

$$\frac{\$0.51*140.8M}{377.2M} + \frac{\$0.24*227.7M}{377.2M} + \frac{\$11.26*8.7M}{377.2M} = \$0.59/gal$$

Equation (IV.6) shows the calculation for the weighted average for steady-state delivery asset O&S costs (*SP_3*) at $0.12 per gallon.

$$SP3: DeliveryAssetO\&S.SteadyState(\$/gal) =$$

$$OP3*\%ShipOps.SteadyState + LandOps(\$/gal)*\%LandOps.SteadyState = \quad \text{(IV.6)}$$

$$\$0.59/gal*0.2087 + \$0/gal*0.7913 = \$0.12/gal$$

4. *Direct Fuel Infrastructure O&S and Recapitalization Costs ($/gal):* We assume the apportioned cost of fuel for direct infrastructure O&S cost during steady-state operations include NAS Fuel Division general supplies and materials and operating lease costs for refueling trucks. Note that operating lease accounting (vice capital lease) necessitates that these costs are O&S funded, thus considered within this cost element (CE_4) rather than CE_2 and CE_3, where a capitalization of the asset would require depreciation cost accounting.

F/A-18E/F operations are primarily conducted at NAS Lemoore and NAS Oceana. This model estimates the steady-state infrastructure costs per gallon using representative data from NAS Lemoore, home station to one third of all F/A-18E/F aircraft. Appendix B, Table 14 displays NAS Lemoore fuel division direct infrastructure costs. The reported fuel division FY09 labor and gallons delivered indicate steady-state direct infrastructure price is $0.02 per gallon.

$$SP4 = \frac{FuelTruckLeaseCost + MiscSupplies\,\&\,Equip}{Total.gal.delivered} = \frac{\$907,476 + \$89,700}{43,747,378} = \$0.02/gal \qquad \text{(IV.7)}$$

In the absence of carrier infrastructure cost breakout data, this study uses the analogy cost estimation method to derive carrier direct infrastructure costs (OP_4). The ratio of direct costs to indirect (labor) costs at NAS Lemoore for FY09 was 0.4919 (Appendix B, Table 14). Equation (IV.8) applies this ratio to estimated operational indirect fuel infrastructure costs (OP_5) determined in paragraph IV.B.5.

$$OP_4 = OP_5 * LandDirectToIndirectCostRatio = \$0.73/gal * .4919 = \$0.36/gal \qquad \text{(IV.8)}$$

5. *Indirect Fuel Infrastructure Costs ($/gal):* This study considered two steady-state operations categories: ship operations non-deployed and land operations non-deployed. As in paragraph IV.B.4., this model estimates the steady-state infrastructure costs per gallon for land operations using

representative data from NAS Lemoore. Appendix B, Table 14 displays fuel division infrastructure costs from NAS Lemoore for FY09. The fuel division estimates steady-state indirect infrastructure costs at $0.05 per gallon. A carrier manpower analysis within the NAVAIR FBCF study provides an estimated $0.70 per gallon for shipboard operations (NAVAIR, 2009).

The estimate for operational indirect fuel infrastructure cost assumes carrier personnel support all shipboard operations, and dismisses the negligible percent of land-based operations (0.5 percent) indirect support costs. We use the NAVAIR calculated $0.70 per gallon adjusted for one year of personnel inflation factor to $0.73 as in equation (IV.9).

$$OP5 = ShipIndirectFuelCost(\$/gal) = \$0.73/gal \tag{IV.9}$$

Next, we mimic the FY08 NAVAIR analysis of naval aviation mission codes (Appendix B, Figure 11 and Table 15) to determine shipboard operating hours (20.87 percent) versus land based operating hours (79.13 percent). We next apply these percentages to corresponding indirect price per gallon in Equation (IV.10) below. The weighted ratio of land and shipboard operations yields an average indirect fuel infrastructure cost at $0.19 per gallon.

$$\begin{gathered} SP5 = LandIndirectCost(\$/gal) * PercentLandOps + \\ ShipIndirectCost(\$/gal) * PercentShipOps = \\ \$0.05/gal * 0.7913 + \$0.73/gal * 0.2087 = \$0.19/gal \end{gathered} \tag{IV.10}$$

6. *Environmental Costs ($/gal):* This cost element has a high potential for variance. Cap and trade legislation or carbon tax costs could be accounted for within this cost element, if applicable to DoD carbon-emitting energy usage. The NAVAIR study concludes a need for consensus on this cost element. An OSD(CAIG) pilot study uses a $0.10 per gallon estimate for HMMWV (OSD(CAIG), 2008) and the draft developmental OSD model plugs the same estimate into calculator versions. The Corley thesis ties environmental costs to a five percent proportion of commodity price. For the sake of comparison consistency, this chapter will do the same. From paragraph IV.B.1., commodity

price is \$2.05, driving an estimate of \$0.10 for each gallon of JP burned (equation (IV.11)). Interestingly, for FY09 average commodity fuel price, five percent of the variable price equates to the often-quoted \$0.10 estimate. For reference, RMI quotes the National Academy of Science calculations for air pollution and climate change within an order of magnitude of this estimate at \$0.14/gal in FY00 dollars (Lovins, Datta, et al., 2005).

$$\begin{gathered} OP6, SP6: EnvironmentalCosts(\$/gal) = \\ CommodityPriceOfFuel(\$/gal) * 5\% = \\ \$2.05/gal * 0.05 = \$0.10/gal \end{gathered} \tag{IV.11}$$

7. *Other Services and Platform Delivery Specific Costs (\$/gal):*

As in the Corley DDG-51 estimate, we use a function that estimates the costs of other services and platform delivery specific costs within a range of estimated values. The ranges of values are bounded by upper and lower limits (OP_{7LL}, OP_{7UL}, SP_{7LL}, SP_{7UL}) determined as a percentage of commodity fuel price (OP_1, SP_1). For the Base Case steady-state scenario (SP_7), we assume the burden will increase from one to two-and-a-half percent of the commodity price of fuel. For the operational scenario (OP_7), we assume the burden associated with fuel delivery will increase within a range from 25 percent to 200 percent of the commodity price of fuel. Equations (IV.12) and (IV.13) display SP_7 and OP_7 cost estimate calculations, respectively.

$$\begin{aligned} SP_{7LL} &= SSlowRange * SP_1 = 0.01 * \$2.05/gal = \$0.02/gal \\ SP_{7UL} &= SSHighRange * SP_1 = 0.025 * \$2.05/gal = \$0.05/gal \end{aligned} \tag{IV.12}$$

$$\begin{aligned} OP_{7LL} &= OPlowRange * OP_1 = 0.25 * \$2.05/gal = \$0.51/gal \\ OP_{7UL} &= OPHighRange * OP_1 = 2.00 * \$2.05/gal = \$4.10/gal \end{aligned} \tag{IV.13}$$

Table 6 is the tabulated summary of computed cost elements. These values are inputs for OSD FBCF calculator (V2) model subsequent analysis. Note since the Corley study, the term Assured Delivery Price (ADP) replaces $FBCF_S$ after OSD Calculator V2. We bring this term into this study and note the interchangeable nature of the terms. The ADP lower and upper limits result because of the range of inputs from the variable CE_7. These values are also the basis of cost estimate inputs for the model used to determine FBCF for F/A-18E/F with OSD(AT&L) calculator V7 in paragraph IV.H.

F/A-18E/F Fully Burdened Cost of Fuel Cost Element Summary (Assured Delivery Price)			
Cost Element	**Description**	**Operational(OP)**	**Steady State(SP)**
CE_1	Commodity Cost of Fuel	$ 2.05	$ 2.05
CE_2	Primary Fuel Delivery Asset O&S Costs	$ 13.80	$ 2.88
CE_3	Depreciation Cost of Primary Fuel Delivery Assets	$ 0.59	$ 0.12
CE_4	Direct Fuel Infrastructure O&S and Recapitalization Cost	$ 0.36	$ 0.02
CE_5	Indirect Fuel Infrastructure Cost	$ 0.73	$ 0.19
CE_6	Environmental Costs	$ 0.10	$ 0.10
CE_7	Other Service and Platform Delivery Specific Costs		
	CE_7 Lower Limit	$ 0.51	$ 0.02
	CE_7 Upper Limit	$ 4.10	$ 0.05
	$FBCF_S$ (Assured Delivery Price) Lower Limit	**$ 18.15**	**$ 5.39**
	$FBCF_S$ (Assured Delivery Price) Upper Limit	**$ 21.74**	**$ 5.42**

Table 6. Base Case Assured Delivery Price cost estimate values

When we input Table 6 values in the FBCF calculator V2, the output is as seen in Table 7. See Appendix C for detailed cost inputs for the developmental calculator used (V2). The upper and lower bounds for ADP, or $FBCF_S$, with operational ($FBCF_{SOp}$) and steady-state ($FBCF_{SSS}$) components, are used in the model to derive an overall OPTEMPO weighted ADP. The model calculator generates $FBCF_D$ using assumptions made for OPTEMPO ratios and fuel demanded per day in the Base Case scenario.

	Operational		**Steady-State**		**OPTEMPO Weighted**	
	$FBCF_{SOp}$	**$FBCF_{DOp}$**	**$FBCF_{SSS}$**	**$FBCF_{DSS}$**	**$FBCF_S$**	**$FBCF_D$**
	$/gal	**$/day**	**$/gal**	**$/day**	**$/gal**	**$/day**
Mean	$ 19.96	$ 3,361,100.18	$ 5.47	$ 1,371,247.57	$ 9.60	$ 1,938,596.17
Median	$ 19.94	$ 3,353,366.97	$ 5.46	$ 1,371,236.32	$ 9.58	$ 1,936,637.13
Std Dev	$ 1.29	$ 217,409.85	$ 0.21	$ 52,151.59	$ 0.39	$ 70,400.39
Mean + 1.65 Std Dev	$ 22.09	$ 3,719,826.44	$ 5.81	$ 1,457,297.70	$ 10.24	$ 2,054,756.82
Mean - 1.65 Std Dev	$ 17.84	$ 3,002,373.92	$ 5.12	$ 1,285,197.44	$ 8.96	$ 1,822,435.52

Table 7. Base Case FBCF estimates for F/A-18E/F

Table 7 provides the output values for operational, steady-state, and OPTEMPO weighted $FBCF_S$ and $FBCF_D$, assuming the scenario with 29% operational environment. The $9.60 per gallon OPTEMPO weighted average ($FBCF_S$) generates a daily fully burdened cost of fuel ($FBCF_D$) of $1.939 million a day. Figure 1 displays the cost estimate inputs derived in paragraphs IV.B.1. through IV.B.7. Definitions of the subscripted variables from FBCF calculator documentation, modified to reflect specific subject and delivery platforms of this study, follow:

- $FBCF_{SOp}$ = cost per gallon of fuel supplied from T-AO, KC, and F/A-18E/F Refueling assets during operational scenario
- $FBCF_{DOp}$ = cost per day of fuel demanded from F/A-18E/F during operational scenario
- $FBCF_{SSS}$ = cost per gallon of fuel supplied by T-AO, KC, and F/A-18E/F Refueling assets during steady-state scenario
- $FBCF_{DSS}$ = cost per day of fuel demanded by F/A-18E/F during steady-state scenario
- $FBCF_S$ = cost per gallon of fuel supplied by T-AO, KC, and F/A-18E/F Refueling assets as a weighted average of operational and steady-state scenarios (OPTEMPO weighted)
- $FBCF_D$ = cost per day of fuel demanded by F/A-18E/F as a weighted average of operational and steady-state scenarios (OPTEMPO weighted)

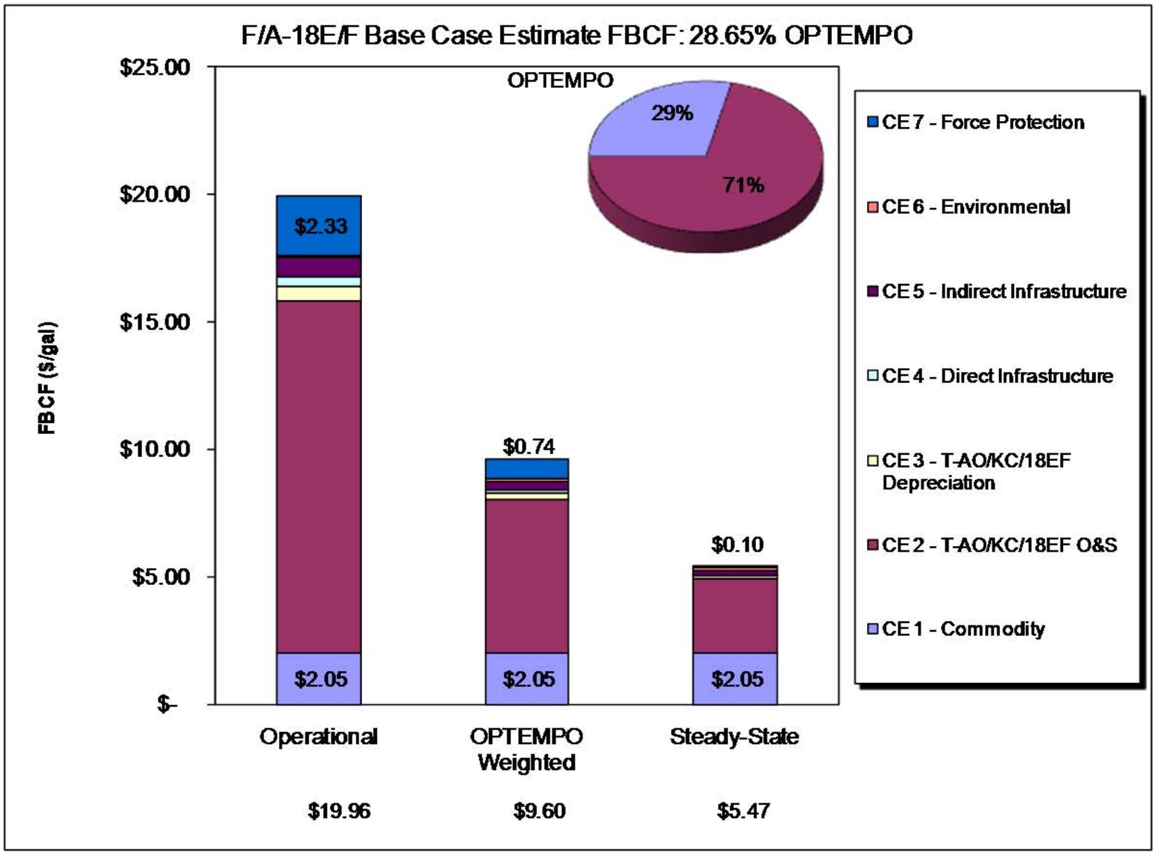

Figure 1. Base Case FBCF estimates for F/A-18E/F

C. IMPACT OF OPTEMPO ON BASE CASE

This section demonstrates the effect on Base Case FBCF resulting from higher and lower OPTEMPO assumptions. Two modifications (Mod 1, Mod 2) permit sensitivity analysis to an OPTEMPO 10 percent higher and lower than the Base Case (39 percent, 19 percent) with all other cost inputs remaining the same.

1. Base Case Mod 1

The first modification to Base Case is a 10 percent lower OPTEMPO set at 18.65 percent. This change drives operational fuel demand a proportional amount lower. Table 8 and Figure 2 display the FBCF calculator V2 numerical results and graphical depiction of Base Case Mod 1.

	Operational		Steady-State		OPTEMPO Weighted	
	$FBCF_{SOp}$	$FBCF_{DOp}$	$FBCF_{SSS}$	$FBCF_{DSS}$	$FBCF_{S}$	$FBCF_{D}$
	$/gal	$/day	$/gal	$/day	$/gal	$/day
Mean	$ 19.91	$ 1,557,173.30	$ 5.46	$ 1,863,291.43	$ 8.14	$ 1,806,480.08
Median	$ 19.91	$ 1,557,553.98	$ 5.46	$ 1,861,790.77	$ 8.14	$ 1,806,295.34
Std Dev	$ 1.35	$ 105,773.45	$ 0.20	$ 66,987.22	$ 0.30	$ 57,771.03
Mean + 1.65 Std Dev	$ 22.14	$ 1,731,699.48	$ 5.79	$ 1,973,820.35	$ 8.63	$ 1,901,802.29
Mean - 1.65 Std Dev	$ 17.69	$ 1,382,647.11	$ 5.14	$ 1,752,762.51	$ 7.66	$ 1,711,157.88

Table 8. Base Case Mod 1: 19 percent OPTEMPO

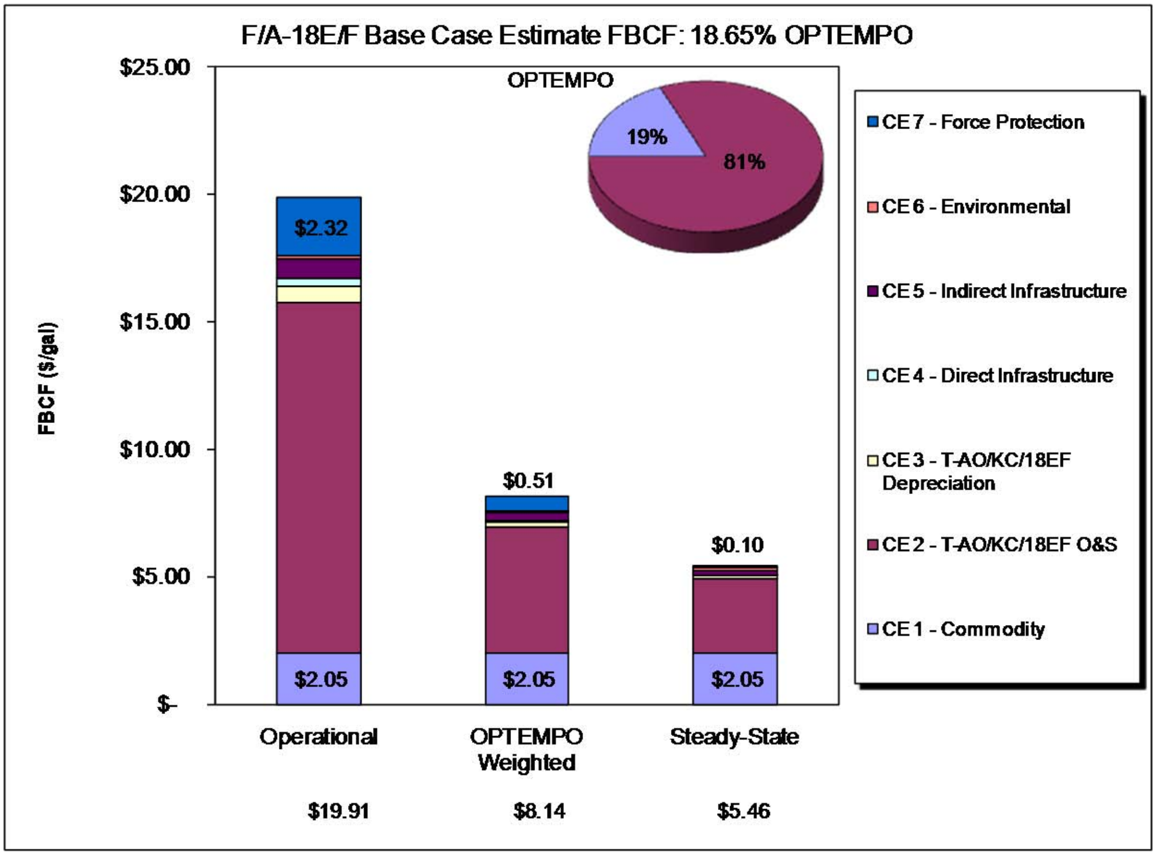

Figure 2. Base Case Mod 1: 19 percent OPTEMPO

The mean OPTEMPO weighted $FBCF_S$ decreased by $1.46 from Base Case because of relatively less time in operational environment. Note that the Steady-state and Operational estimates remain relatively constant, within one-half of a percent, but vary slightly due to the effects of Monte Carlo simulation.

When comparing Base Case Mod 1 $FBCF_{SOp}$, $FBCF_{DOp}$, $FBCF_{SSS}$ and $FBCF_{DSS}$, it is apparent that they all remain within one-half percent of the Base Case values. The significant reduction in $FBCF_S$ and $FBCF_D$ is apparent as the

Mod 1 scenario is subjected to less operational time, requiring fewer gallons at relatively expensive $FBCF_{SOp}$ prices, and more gallons at the relatively inexpensive $FBCF_{SSS}$. The result is smaller transportation and security force prices as OPTEMPO weighted $FBCF_S$ falls from $9.60 in the Base Case to $8.14 in Base Case Mod 1.

2. Base Case Mod 2

The second modification to the Base Case is a 10 percent higher OPTEMPO set at 38.65 percent. This drives operational fuel demand a proportional amount higher. Table 9 and Figure 3 display the FBCF calculator V2 numerical results and graphical depiction of Base Case Mod 2.

	Operational		Steady-State		OPTEMPO Weighted	
	$FBCF_{SOp}$	$FBCF_{DOp}$	$FBCF_{SSS}$	$FBCF_{DSS}$	$FBCF_S$	$FBCF_D$
	$/gal	$/day	$/gal	$/day	$/gal	$/day
Mean	$ 19.89	$ 3,223,260.33	$ 5.46	$ 1,405,541.68	$ 11.01	$ 2,104,669.16
Median	$ 19.87	$ 3,223,819.29	$ 5.47	$ 1,406,453.40	$ 11.02	$ 2,104,889.31
Std Dev	$ 1.33	$ 215,813.57	$ 0.21	$ 52,906.14	$ 0.54	$ 91,473.80
Mean + 1.65 Std Dev	$ 22.09	$ 3,579,352.73	$ 5.80	$ 1,492,836.81	$ 11.90	$ 2,255,600.92
Mean - 1.65 Std Dev	$ 17.70	$ 2,867,167.94	$ 5.13	$ 1,318,246.56	$ 10.13	$ 1,953,737.40

Table 9. Base Case Mod 2: 39 percent OPTEMPO

Note the increase in OPTEMPO weighted $FBCF_S$ is approximately the same as the decrease in Base Case Mod 1 ($1.41 versus $1.46). This is reasonable, as the percent of OPTEMPO change was identical in the opposite direction.

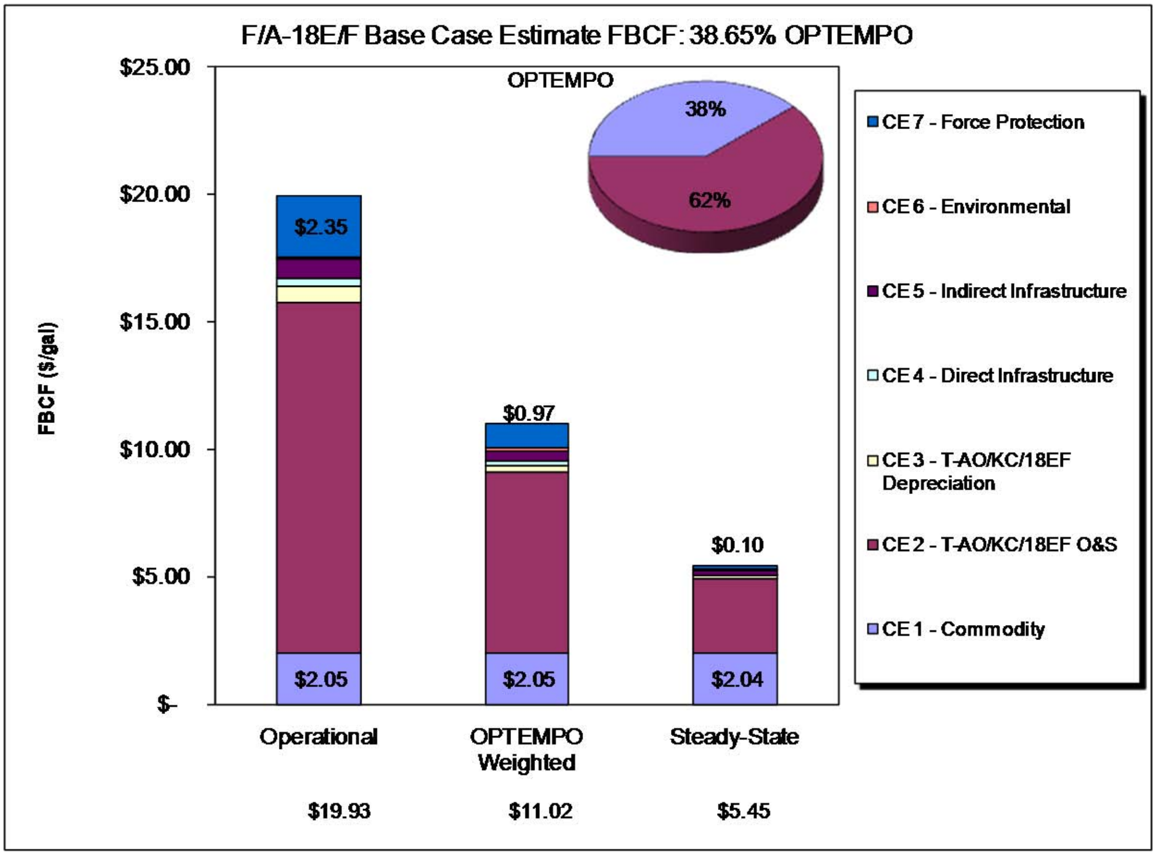

Figure 3. Base Case Mod 2: 39 percent OPTEMPO

> In Figure 3, note the increase in OPTEMPO weighted $FBCF_S$ as Operational and Steady-state estimates again remain within one-half percent of Base Case values. Note the slight adjustment to assumed OPTEMPO rate as the rounded value of 38 percent, presented in the pie chart, results due to Monte Carlo iterations.

Just as in the Base Case Mod 1 comparison, $FBCF_{SOp}$, $FBCF_{DOp}$, $FBCF_{SSS}$ and $FBCF_{DSS}$ remain within one-half percent of the Base Case values. In this case, attributable to increased operational exposure, $FBCF_S$ increases $1.42 from $9.60 to $11.02 per gallon. More gallons of fuel are delivered at the relatively expensive $FBCF_{SOp}$ estimated $19.93 per gallon and fewer gallons at the relatively inexpensive $FBCF_{SSS}$ estimated $5.45 per gallon (see Table 10).

When OPTEMPO percentages adjust equally up and down for sensitivity analysis, the resulting OPTEMPO weighted $FBCF_S$ absolute value difference from Base Case estimates is nearly equivalent. This is as expected and represented in Table 10 and Figure 4.

	Operational	Steady State	OPTEMPO Weighted
	$FBCF_{SOp}$ (\$/gal)	$FBCF_{SSS}$ (\$/gal)	$FBCF_S$ (\$/gal)
Base Case (29/71 OPTEMPO)	$ 19.96	$ 5.47	$ 9.60
Mod 1(19/81 OPTEMPO)	$ 19.91	$ 5.46	$ 8.14
Difference from Base Case %	-0.3%	-0.2%	-15.2%
Mod 2 (39/61 OPTEMPO)	$ 19.93	$ 5.45	$ 11.02
Difference from Base Case %	-0.2%	-0.4%	14.8%

Table 10. FBCF weighted element comparison of Base Case to Mod 1 and Mod 2

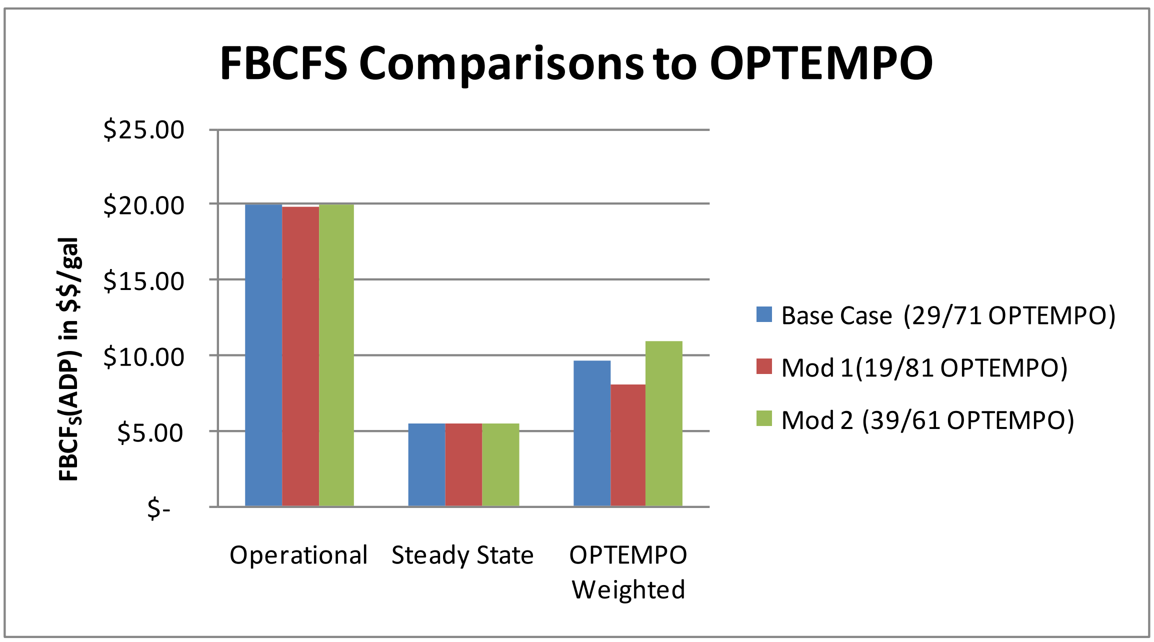

Figure 4. FBCF weighted element comparison of Base Case to Mod 1 and Mod 2

Sensitivity analysis reveals the effects of 10 percent OPTEMPO adjustments. Both modifications result in 15 percent changes in OPTEMPO weighted $FBCF_S$. Note the Monte Carlo simulation produces only minor Operational and Steady-state estimated $FBCF_S$ component differences.

D. IMPACT OF BASE CASE FBCF ESTIMATE ON LCC

Differentiating the fuel-related life-cycle costs alternatively using commodity price then $FBCF_S$ price yields the total impact of fully burdened fuel requirements on aircraft O&S LCC. This represents a rough analysis projecting a single year of FBCF costs over the expected life span of the F/A-18E/F.

$$\begin{gathered} FA18FuelLCC.Commodity = \\ FA18Lifespan(yrs) * FA18AnnualJP(gal) * FuelPrice(\$/gal) = \\ 18yrs * 153,800,976gal * \$2.05 = \$5,675M \end{gathered} \tag{IV.14}$$

$$\begin{gathered} FA18FuelLCC.FBCF = \\ FA18Lifespan(yrs) * FA18AnnualJP(gal/yr) * FBCF_S(\$/gal) = \\ 18yrs * 153,800,976gal * \$9.59 = \$26,549M \end{gathered} \tag{IV.15}$$

Total life-cycle cost impact due to FBCF is the difference between results in equations (IV.14) and (IV.15), or $20,874 million. As a reminder, this result assumes the constant dollar DESC price is fixed throughout the 18-year O&S period of analysis, although future fuel prices are varied and unpredictable.

E. FBCF ESTIMATES VERSUS COMMODITY AND STANDARD PRICES

Of comparison interest are the mean Operational, Steady-state, and OPTEMPO weighted $FBCF_S$ estimates versus the calculated commodity price (OP_1, SP_1) and DESC standard price from paragraph IV.B.1. See Table 11 and Figure 5 for the commodity price comparisons. The essence of this study is to highlight the large disparity as a commodity price multiple increase, not fractional increase, to fuel delivery and security related costs. The mean $FBCF_{SSS}$ is 266 percent, and the mean $FBCF_{SOp}$ is 972 percent of the calculated commodity price. This effectively translates to a DoD funding requirement to support the higher burden placed on the logistics tail. Using the $FBCF_S$ from Base Case and two sensitivity analysis modifications, Equation (IV.16) generates the mean OPTEMPO weighted $FBCF_S$, which we use in later comparative analyses.

$$MeanOPTEMPOWeighted.FBCF_S(\$/gal)=$$
$$\frac{BaseCaseFBCF_S+Mod1FBCF_S+Mod2FBCF_S}{3}= \qquad \text{(IV.16)}$$
$$\frac{[9.60(\$/gal)+8.14(\$/gal)+11.02(\$/gal)]}{3}=\$9.59/gal$$

This study quantifies the higher logistics burden at 368 percent of the F/A-18E/F fuel costs ($2.05 per demanded gallon for F/A-18E/F squadron Flying Hour Program funds and $7.54 per gallon for various logistics support commands, $9.59 per gallon total).

	Operational	Steady State	OPTEMPO Weighted
	$FBCF_{SOp}$ ($/gal)	$FBCF_{SSS}$ ($/gal)	$FBCF_S$ ($/gal)
Commodity Price	$ 2.05	$ 2.05	$ 2.05
Mean $FBCF_S$ (all cases)	$ 19.93	$ 5.46	$ 9.59
% of Commodity Price	972.4%	266.3%	467.6%

Table 11. Mean FBCF estimates versus calculated commodity price

Table 11 provides the mean $FBCF_S$ for Base and Mod cases computed as in equation (IV.16). The mean OPTEMPO weighted average $FBCF_S$ is $9.59.

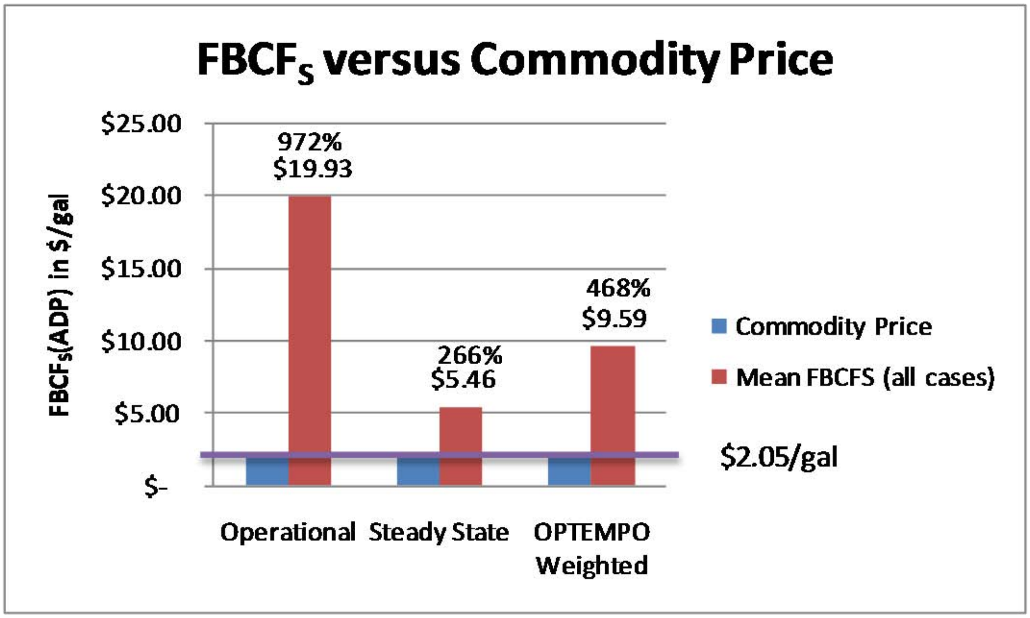

Figure 5. Comparison of mean FBCF estimates to calculated commodity price

Note the increase in price from 266 percent of commodity price during steady-state operations to 972 percent during operational scenarios.

Figure 6 compares the mean OPTEMPO weighed FBCF$_S$ estimate with calculated commodity price and standard DESC price. New to the analysis is the similar difference of DESC standard price to mean FBCF$_S$.

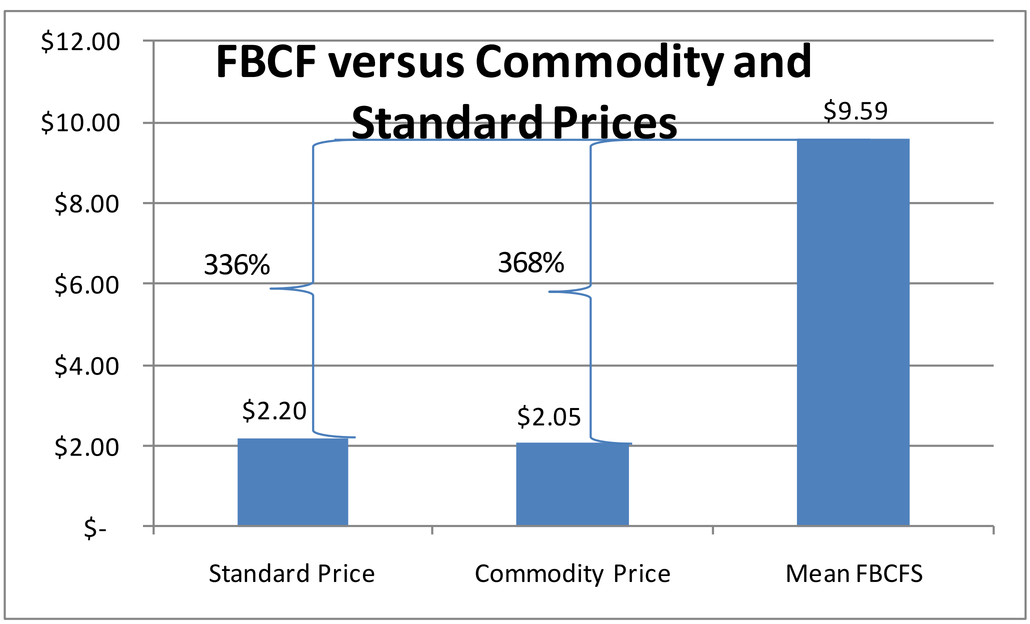

Figure 6. Comparison of mean OPTEMPO weighted FBCF$_S$

Figure 6 compares standard price (time weighted) and calculated commodity price to the mean FBCF for the Base Case OPTEMPO weighted scenario. The mean $FBCF_S$ is 336 percent higher than computed weighted average DESC standard fuel price for FY09, slightly smaller than the computed difference from commodity price. The FBCF is 368 percent higher than the reported cost per gallon average commodity price for all F/A-18E/F in FY09. Even before consideration of all logistics support pyramid factors in the model, the true cost of a gallon of JP fuel is, at a minimum, 336 percent higher than the time weighted DESC standard price of fuel.

F. CONTRASTING DDG-51 ANALYSIS WITH F/A-18E/F ANALYSIS

In this section, we contrast the results of F/A-18E/F analysis with Corley's DDG-51 analysis. We include the significant quantitative results, analysis approach, platform operating environment, and cost estimation methods that influence the conclusions of this platform specific study.

1. Commodity Price Multiplier Comparison

A comparison of commodity fuel price to ADP results in a "Commodity Price Multiplier" for both platforms. The DDG-51 study yielded a Commodity Multiplier of 1.666. In other words, for every dollar spent on fuel at the commodity price, DoD spent $1.67 to purchase, deliver and secure the fuel. In comparison, the commodity multiplier is 4.678 for the F/A-18E/F, nearly three times the impact.

2. Standard Price Multiplier Comparison

A comparison of standard fuel price to ADP results in a "Standard Price Multiplier" for both platforms. The DDG-51 study yielded a Standard Price Multiplier of 2.259 compared to a multiplier of 4.359 for the F/A-18E/F, roughly twice the impact. We can explain the reduced gap in multiples largely by the greater percent difference in commodity price from DESC standard price. The DDG-51 example increases the standard price multiplier because its standard price (in the multiplier denominator) was 36 percent lower than the commodity price. In this study, the standard price was seven percent higher, reducing the multiplier.

3. Operational to Steady-State ADP Relative Comparison

The mean operational ($FBCF_{SOp}$) to steady-state ($FBCF_{SSS}$), or assured delivery price ratio for DDG-51 study was 1.69, compared to F/A-18E/F at 3.65.

$$\frac{DDG51.FBCF_{SOp}}{DDG51.FBCF_{SSS}} = \frac{\$8.19}{\$4.86} = 1.69 \qquad \text{(IV.17)}$$

$$\frac{FA18EF.FBCF_{SOp}}{FA18EF.FBCF_{SSS}} = \frac{\$19.93}{\$5.46} = 3.65 \qquad \text{(IV.18)}$$

The relative effect on fuel delivery logistics when deploying the F/A-18E/F platform is more than twice the effect of deploying a DDG-51. The assured delivery price increase from steady-state to operational ADP is roughly 70 percent of the steady-state assured delivery price for DDG. In contrast, the ADP for F/A-18E/F suffers a 265 percent increase.

4. DDG-51 and F/A-18E/F Analysis Approach Contrasts

The approach for cost element ($CE_{2\text{-}6}$) calculations in this study differed vastly from the DDG-51 study due to operating environment support requirements and the definition of operational and steady-state. These differences may be useful to cost estimators when developing recommendations and final guidance from OSD(AT&L) for platform specific or service specific FBCF analysis methods.

We defined steady-state as non-deployed land and CONUS-based ship operations. The DDG-51 study operational and steady-state cost elements are identical for $CE_{1\text{-}6}$ ($OP_2 = SP_2$, $OP_3 = SP_3$, etc.) (Corley, 2009). The F/A-18E/F FBCF delivery vehicle costs calculations in SP_2 and SP_3 are significantly different than OP_2 and OP_3 in that fuel deliveries for NAS based aircraft do not generally require a delivery platform. Any fuel delivery vehicle costs were shifted to SP_4

considering fuel trucks as operational leases. The shipboard activities require all three primary fuel delivery assets, and factor into the steady-state cost component based on the weighted average of actual flight hours.

The studies differ in O&S costs calculation for T-AO fuel delivery. This study gave preference to MSC working capital fund financial reporting data, including T-AO and T-AOE supply ships. Corley's theses used VAMOSC costs data and reported fuel delivered by T-AO ships only.

Direct and indirect infrastructure costs (CE_4, CE_5) in this study used inference approach using NAS Lemoore representative data. Corley estimated these using a proportion (20 percent) of VAMOSC actual total infrastructure cost data reported for ports serving DDG-51 activity.

G. IMPROVED LIFE-CYCLE COST ESTIMATE WITH O&S PHASING

In paragraph IV.D., we estimated LCC for fuel based on a single year of consumption demand (FY09). The analysis relied on an assumption that the FY09 force structure number of aircraft represents FOC and does not vary throughout the O&S phase. It assumed fuel demand would not rise or fall during the life cycle. These facts would suggest a uniform distribution of aircraft and fuel demand over an 18-year period.

A more thorough analysis takes into account the time-phased nature of the F/A-18E/F deployment schedule. In this section, we use a parametric approach to cost estimation using actual historical fuel consumption data and projected F/A-18E/F aircraft count to estimate the total platform life-cycle fuel demand. We create a CER to predict the dependent variable, fuel demand per year, based on the independent variable, total aircraft count. We used the following data sources mapped to different periods of the O&S life cycle depicted in Figure 7.

(1) VAMOSC historical data for FY99 to FY09

(2) A subset of the OPNAV N882 Aircraft Program Data File (APDF) force deployment schedule for FY10 to FY17,

(3) Life span assumption (18 years) for phase-out of aircraft from FY17 to FY31

We use the CER to predict the annual JP demand from expected total aircraft count. We infer total number of aircraft count expected to report costs in VAMOSC. To predict the phasing out of aircraft from FY17 to FY31 at the end of the life cycle O&S phase, we assume no programs to extend service life. The phase out begins in FY17 based on actual aircraft ages, consistent with the aircraft replacement schedule in the APDF. Applying the ADP to calculated life-cycle fuel demand, we arrive at a total LCC for fuel. In this way, we overcome the limitation of looking at only one year of consumption demand data. We developed a CER using regression techniques on VAMOSC FY02 to FY09 data. Fuel barrels consumed (in gallons) is the dependent variable, and aircraft count is the independent variable. The CER in equation (IV.19) below estimates fuel consumption based upon total aircraft count. The regression is significant at a 96.6 percent confidence level (F= 0.00373, and R^2 = 0.958), which represents a very satisfying fit to the data.

$$\begin{gathered} AnnualGalConsumed(gal) = \\ 6{,}970{,}942(gal) + 424{,}923(gal\,/\,Aircraft) * VAMOSCCount(Aircraft) \end{gathered} \tag{IV.19}$$

We represent projected fuel consumed and LCC fully burdened fuel cost estimates in Figure 7. In the previous analysis (Chaper IV, Section D), we assume a uniform distribution of O&S costs. Here we see what appears to be a normally distributed FBCF demand and aircraft count based on aircraft count over the O&S life cycle from FY99 to FY31. Under this analysis, we estimate 3.2B gallons of JP consumed at a total cost of $30.7B in FY09$. This estimate is $4.2B, or 15.8 percent larger than the estimate from section IV.D. See Appendix D, Table 18 and Table 19, for improved LCC CER supporting data.

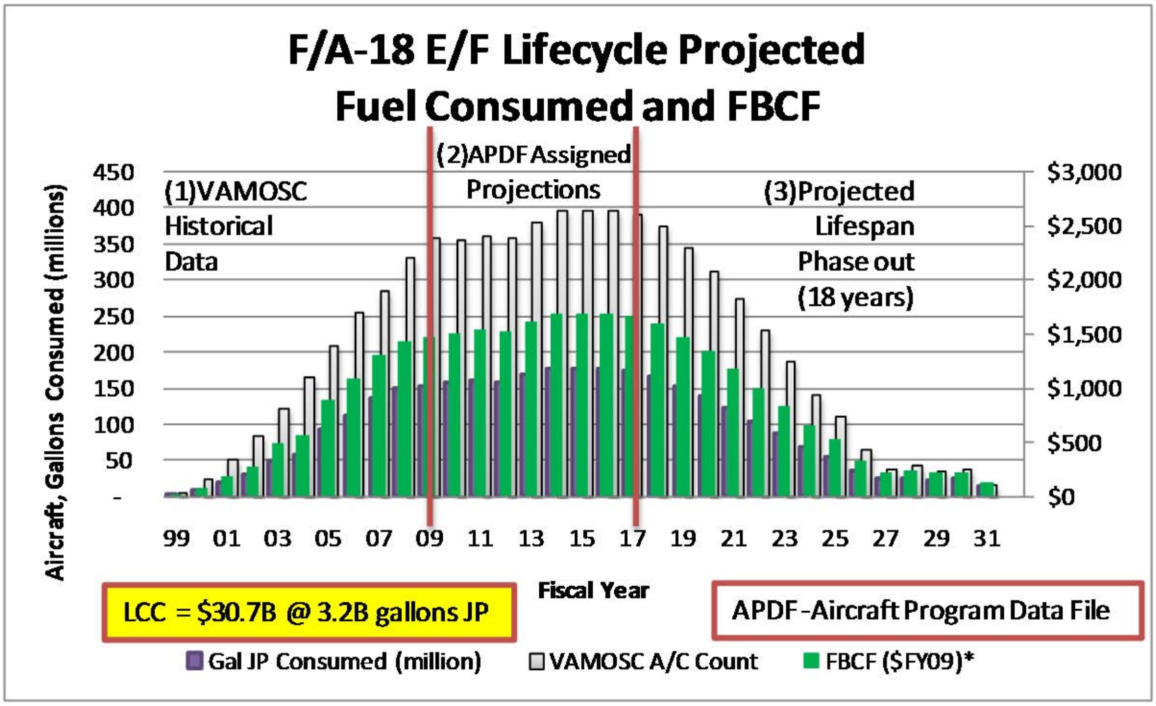

Figure 7. Life cycle projected fuel demand and FBCF from A/C count

H. OUSD CALCULATOR WITH PROPOSED PRICE ELEMENT UPDATES

This section addresses developments in the OSD FBCF calculator beyond previous baseline cost estimates. At the time of this study, calculator V7 remained pre-decisional, primarily due to a Director of Operational Energy Plans and Programs (OSD[AT&L][DOEPP]) position awaiting final U.S. Senate confirmation. This version included updates that provide a method to account for estimated combat losses, or attrition, of support assets. The calculator description centers on the three Operational Price Elements (OP_2, OP_3, and OP_7) most commonly computed for operational scenarios (Cotman, 2010). Keeping the Price Element data the same for all other components of the V2 calculator, we observe the necessary data collection and manipulation required to fulfill the objectives of the most recent developmental calculator.

1. FBCF Calculator V7 Scenario Overview

This scenario evaluates only T-AO delivered fuel servicing four carriers with six oilers escorted by two destroyers with no use of escort aircraft. The calculator results in Appendix E, Table 20 include environment specific ADP_O and ADP_S, and overall weighted ADP in dollars per gallon and FBCF in dollars per day to be applied to all aircraft quantified in the scenario. This process would have to be repeated for KC tanker and F/A-18E/F refueling scenario data, adding each *OP_2, OP_3, and OP_7* result together to serve as calculator inputs for combined scenario F/A-18E/F specific FBCF. The sea based T-AO fuel delivery scenario description, scenario diagram and calculator inputs are notional, displayed in Figure 8 Figure 8. and Table 12.

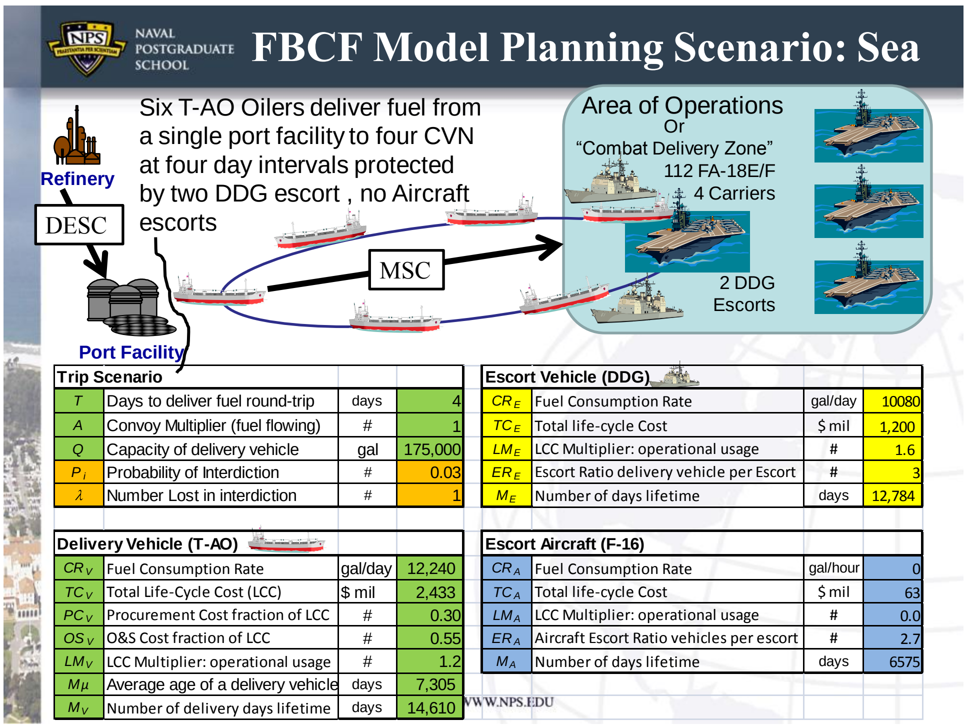

Figure 8. FBCF calculator V7 scenario diagram and input data

Symbols	Scenario Parameter Name (units)	Operational	Steady-State
OR	OPTEMPO Ratio (#)	0.29	
P_O	System Proportion (Operational) (#)	0.577	
P_S	System Proportion (Steady-State) (#)		0.831
D_O	Total fuel Demanded at final delivery location (Operational) (gal/day)	620,000	
D_S	Total fuel Demanded at final delivery location (Steady-State) (gal/day)		550,000
N_O	Number of vehicles located at final delivery location (Operational) (#)	112	
N_S	Number of vehicles located at final delivery location (Steady-State) (#)		108

Table 12. Scenario inputs for V7 calculator

2. FBCF Calculator V7 Input Description and Results

The FBCF Calculator V7 incorporates the concept that more than just fuel demanded by the platform of study and primary delivery vehicle is expended to deliver and protect delivered fuel. In addition to demand at delivery location (D_O), there is a fuel loss due to interdiction of delivery vehicles (α), and fuel burned by all delivery and escort aircraft (ΣCi). It implements a term for the total fuel loaded for delivery (L) as the sum of that daily platform demand D_O, the α loss, and the ΣCi sum of all fuel consumed by delivery vehicle (V), escort vehicle (E), and escort aircraft (A) assets. Equation (IV.20) specifies this relationship.

$$\begin{gathered} L = Do + \alpha + \sum Ci \\ i = V, E, A \end{gathered} \tag{IV.20}$$

<u>a. Calculator input sources and considerations:</u> Reference the macro scenario input parameters in Table 12. OPTEMPO ratio (OR) is determined as in V2, system proportion (P_O) and total fuel demanded (D_O) are inferred by reviewing FOCR information. During a five-month span of CVW-8 carrier deployed operations, two F/A-18E/F squadrons consumed 57.7 percent of 155,000 gallons daily carrier demand total. The four carrier scenario demand is four times that, or 620,000 gallons per day. P_S and D_S are the equivalent system proportion of fuel demanded at home base NAS, with demand proportional to number of aircraft at delivery locations.

<u>b. OP_2 calculation and results</u>: The scenario results in an operational O&S price of $4.35 per gallon. This value is smaller than, but incomparable to, the V2 OP_2 calculation, because the notional scenario demand and number of delivery ships differ from historical actual data used in V2. Recall this V7 analysis considered only the T-AO delivery component.

<u>c. OP_3 calculation and results</u>: The scenario results in a primary fuel delivery vehicle depreciation price of $19.95 per gallon. These results tend to be much larger than from the V2 calculator because they take into account the value

of lost assets due to attrition. Sensitivity testing to probability of interdiction (P_i) shows assured delivery price is proportional to the P_i. For every one percent probability change, ADP_O changed $5.90 per gallon.

d. OP_7 calculation and results: The scenario results in additional fuel delivery and security costs of $2.04 per gallon. This figure lies within the lower and upper limits estimated in paragraph IV.B.7., but is subject to the same incomparable limitations as in the OP_2 calculation above. OP_7 is highly dependent on the Total LCC (TC_i) and a LCC multiplier (LM_i). The intent of the multiplier is to adjust the peacetime derived LCC costs to the operational realities of increased wear, battle damage, and additional support costs (Cotman, 2010). The multiplier appears difficult to determine consistently on a department wide basis. Moreover, lack of consistency across services will present planning problems.

3. FBCF Calculator V7 Observed Limitations

a. The V7 calculator methodology assumes the fuel types consumed by delivery vehicles, escort vehicles, and escort aircraft are the same as the platform demanding fuel. In our scenario, the demand (D_O) is for JP while the delivery and escort vehicles burn marine diesel fuel. Where the commodity price of fuel types differ substantially, the calculator would yield inaccurate ADP and FBCF estimates.

b. One significant utility of the V7 calculator is the ability to isolate fuel delivery vehicle FBCF components. Cost estimators can isolate the air refueling component with spreadsheet file FBCF Calculator v7.0 (Interdicted Air).xls, modified to evaluate a scenario involving airborne tankers and escort aircraft. Currently, this is also a limitation to estimating complicated scenarios involving multiple delivery vehicles and their associated scenario factors such as fuel type consumed. Subsequent versions should consolidate the modified calculators to accommodate cost estimations of the complex scenarios.

c. Carefully designed calculator inputs will nullify unwanted cost contributions of escort vehicles and escort aircraft. In our scenario to eliminate the escort aircraft contribution to required fuel loadout (C_A term in equation (IV.20)), we applied a near zero value to the input fuel consumption rate (CR_A) of the escort aircraft. Near-zero values are required to avoid "divide by zero" errors. As in all calculator versions, the range between 5th and 95th percentile inputs must be greater than zero to avoid calculator errors. To eliminate the aircraft consumption contribution to OP_7, a near zero value must be applied to the LCC multiplier (LM_A) of the escort aircraft. See Appendix F for further description of variable L and OP_7 calculations in the OUSD(AT&L) FBCF V7 calculator documentation.

d. Using the V7 pre-decisional model to compute life-cycle FBCF costs necessitates additional considerations for input nuances and life-cycle cost estimates. While the cost factors may be difficult to determine, they are useful to cost estimators. For example, they support cost estimates in the early stages of a program, much as in AoA calculations, which usually rely on analogies to other similar programs or platforms. Any scenario input must take into consideration the total carrier deployment requirements. This scenario combines all worldwide carrier operations and oiler operations into one fuel delivery cycle, whereas Defense Planning Scenarios will require several carriers in one geographic region and others in separate regions. Frequently these are expressed in average presence numbers. For example, it may be determined that for the next 10 years there will be a requirement for 2.2 carriers stationed in the Gulf States region. Some carrier air wings employ three F/A-18E/F squadrons, more than the two that this scenario assumed. As the deployment schedule continues through FOC, an increasing N_O value translates into a larger system proportion (P_O) in addition to increasing the total fuel demand at the carrier location (D_O).

The Monte Carlo simulation was effectively used to model and account for the varied number of F/A-18E/F models deployed throughout an individual fiscal year. Similar to the Base Case analysis in paragraph IV.G., a large range in number of aircraft deployed (N_O) values and home based steady-state (N_S) values does not account for a normally distributed deployment life cycle. An increasingly accurate life-cycle cost estimate would use planned platform deployment schedules and phase-out method similar to section IV.G. Therefore, to determine the total FBCF for V7 scenarios, cost estimators should use an iterative process applying projected deployment and fuel demand evaluated year by year. Resulting deterministic averages are then summed in a table for life-cycle cost totals.

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V. CONCLUSIONS AND RECOMMENDATIONS

If the DoD is to achieve the objectives set forth in Presidential Order 13423, energy efficiencies must be gained through improved sources and reducing wasteful practices. Without an executable, repeatable, fair approach to measuring the true costs of fuel demand, DoD leaders are destined to make acquisition and execution decision errors that perpetuate inefficiencies. The perceived "fully" burdened cost of fuel will remain only "partially" burdened unless clear joint guidance is available to provide a methodology to both require and aid cost estimators to account for the true value of all logistical support, including our most precious resource, human life. We present the conclusions from this study on strategic, operational, and tactical levels and offer recommendations relevant to respective FBCF issues.

A. STRATEGIC CONCLUSIONS AND RECOMMENDATIONS

This section provides a list of conclusions and recommendations that support actions that improve execution of a DoD-wide FBCF strategy.

<u>Aviation is the strategic place to focus FBCF cost savings.</u> We observe in comparing DDG-51 ship FBCF commodity price multiple to aviation (F/A-18E/F) multiple, that the aviation commodity price multiple is significantly higher for navy tactical aircraft than for surface ships. Where ship FBCF adds a large *fraction* (plus 2/3) of commodity price to transport and secure fuel, aviation FBCF adds *multiples* (3.7 times) of the commodity price. Together with the fact that DoD spent approximately $9.9B in FY05 on aviation fuel (DSB, 2008; Lovins, 2010), commodity price multiple magnitude supports the LMI recommendation that military aviation is one of the three focus areas in which we can achieve the greatest impact in fuel efficiency investments. Combined with the RMI assertion that aviation assets constitute the largest percentage of DoD fuel demanding vehicles, there is an opportunity to develop innovative capabilities motivated and informed by the FBCF.

Recommendation: DoD should emphasize accurate FBCF calculations supporting the value of research and development investments in aviation fuel efficiency programs that increase endurance or reduce O&S costs for air refueling assets.

Naval aviation is at risk of adverse MDA decisions. The strategic implications, congressional mandates, and DoD existing policy guidance necessitate attention to the developing field of Fully Burdened Cost of Fuel cost estimation. At the forefront of fuel consumption and high concentration of acquisition funds, DASN(Air) MDAPs are the Navy programs most impacted by FBCF legislation and requirements. Naval aviation is at risk of unfavorable MDA program milestone decisions, which may lead to schedule setbacks or MDAP funding loss if DON does not advance FBCF calculation methodology.

Recommendation: DoD and the services should begin making fuel-conserving technology investments based upon conservative FBCF calculations whose included cost elements are approved by the appropriate DoD or service's MDA. OUSD should create an objective process with policies to incrementally introduce more cost factors into the FBCF estimation rubric.

DoD faces FBCF methodology application consistency challenges. This study used a wide range of assumptions and cost estimating techniques to derive a FBCF for the F/A-18E/F. The DSB indicates cost estimating approach consistency concerns and recommendations from the naval aviation cost estimating professionals signal a need for an oversight office to provide consistent capability-specific direction. OUSD(AT&L) provides the policy guidance, but it is still subject to largely differing applications. The NAVAIR study conclusion supports a need for a consensus on the most complex and underdeveloped cost elements including environmental costs.

Recommendation: The OUSD Cost Assessment and Program Evaluation (CAPE) should issue FBCF cost estimation standards and publish reasonable ranges of price elements, and minimum levels of indirect cost considerations. This will foster more consistency across services and program offices that are proponents for like capabilities.

B. OPERATIONAL CONCLUSIONS AND RECOMMENDATIONS

This section provides a list of recommendations applicable to offices or services for aviation capabilities short of a DoD-wide strategy.

O&S costs for fuel delivery vehicles is the largest price element for an aviation fuel demanding system. We conclude Primary Fuel Delivery Asset O&S cost is the largest of all F/A-18E/F FBCF price elements. The Operational Price element (OP_2) involves the weighted average of three primary fuel delivery platforms. In an operational environment, the O&S cost per gallon is equivalent to a range six to seven times the commodity price of fuel. Of the vehicles that deliver fuel to the F/A-18E/F, the air refueling assets contribute most (97 percent) to this price element. Our research supports the Rocky Mountain Institute's assessment that the biggest delivery cost savings are in the area of aerially refueled aircraft, and indirectly that endurance is a critical attribute to be added to DoD JCIDS list of key capabilities (Lovins, 2010).

There are lessons to learn from FBCF firsts and cross-service coordination. Although Navy MDAPs are not first in line, the NDAA timeline requires that SECDEF implement FBCF policy by October 2011. The Navy can learn from MDAP program offices subject to the first MDA post-implementation decisions, and close coordination with offices that perform similar FBCF calculations and those offices that will provide planning information to program offices.

Recommendation: NAVAIR and other Navy system commands participate in constructive methodology development with OUSD(AT&L). Therefore, the Navy should benefit from lessons learned and best practices in pilot studies or first-in-line MDAP programs such as the Ground Combat Vehicle and Joint Light Tactical Vehicle. The Navy should also partner with HQ USAF to determine the best data sources and cost estimation modeling techniques to support the aviation specific burdened fuel cost contribution to aircraft TOC. NAVAIR should emphasize coordination efforts with OPNAV offices that are responsible for translating Defense Planning Scenarios into cost planning factors usable in FBCF calculators.

FBCF for naval aviation fixed wing platform is multiple times that of the commodity price of fuel. This study verified that FBCF impact is multiples times the commodity price of fuel, and many times more expensive than surface delivered fuel. Even when following OSD(AT&L) guidance considered highly conservative by private scientific research at the Rocky Mountain Institute, programs with heavy reliance on fuel delivery logistics can benefit from alternative technology investments which were evaluated as cost effective during an informed AoA.

Recommendation: Same recommendation applies as for the strategic conclusion concerning adverse MDA decisions.

FBCF calculations are complex for multiple fuel delivery assets. The complexity of calculating fully burdened cost of fuel rises when multiple fuel delivery assets are required. Tactical aviation platforms receive fuel from multiple sources, so the data required come from a multitude of inter- and intra-service reports and databases. Weighted averages are necessary to paint the demand picture across all operational scenarios as recommended in the 2008 DSB study.

Recommendation: If DoD is to produce accurate estimates for future refueling requirements, it must demand and propose a cost-effective way for the VAMOSC system to incorporate more fuel-specific installation and delivery platform infrastructure cost breakdown. Fuel infrastructure direct and indirect costs should be disaggregated from other support costs. NCCA should input existing aviation cost report fuel details into the VAMOSC database. Where insufficient, reports must begin to include this greater detail. As increased reporting in itself causes time and efficiency burdens, new requirements motivated by cost efficiency metrics should be carefully introduced.

C. TACTICAL CALCULATIONS AND RECOMMENDATIONS

This section provides a review for a select group of list of recommendations to aid those conducting aviation related FBCF calculations and cost estimation studies.

Platform specific historical data yields most accurate OPTEMPO rates. During this study, we used multiple bases to allocate costs. Cost allocation ratios were based upon: per gallon delivered, per F/A-18E/F flight hour, and per F/A-18E/F aircraft count. Cost estimators may tend to use the most readily accessible data source. For example, we found NAVAIR had determined an operational flight hour OPTEMPO percentage, inclusive of all Navy TMS aircraft as seen in Appendix B, Table 16. It was more accurate for this platform specific study to quantify OPTEMPO using only tactical aircraft hours, or even better, F/A-18E/F hours. Had we used all Navy aircraft hours to determine OPTEMPO ratios in this study, land-based aircraft (e.g., P-3) deployed flight hours would tend to raise tactical aircraft OPTEMPO, resulting in an artificially high weighted Assured Delivery Price ($FBCF_S$).

Recommendation: When leveraging previous FBCF studies ensure the data upon which basis of cost allocations are applicable to the specific platform operations. If not valid, cost estimators should collect platform specific data.

Calculating price element 1: The commodity price of fuel. As a commodity, fuel prices vary due to market supply and demand. Due to the nature of a WCF, cost estimators must keep in mind that the prices are adjusted to achieve a zero net operating result in the revolving fund for the previous fiscal year. To illustrate, FY09 began with a JP-5 standard price of $4.09 per gallon but averaged just half of that price at $2.05 per gallon over the full year. This study used the aggregate fuel costs reported in VAMOSC for all TMS aircraft and dividing by total JP consumed by those aircraft.

Recommendation: When estimating the cost element for commodity prices, make calculations based on actual reported costs per gallon over a fiscal year or years. OSD should consider modifying guidance for this price element. Multiple year data, adjusted to a constant year, may better represent commodity fuel market price fluctuations. When considering future planning scenario calculations, commodity price projections weighted by historical or projected usage should prove a sufficient technique.

Calculating price element 3: The depreciation costs of primary fuel delivery vehicles. The DAG and OSD calculator methodology description suggest the use of straight line depreciation of fuel delivery vehicles in price element three and escort vehicles and aircraft in price element seven. However, the depreciation dollars are derived from the book value of investments made many years earlier when asset prices were far lower than current prices.

Recommendation: RMI recommends use of an asset's current replacement cost over acquisition book values (Lovins, 2010). At a minimum, the value of those assets lost to attrition (see Appendix F, Equation 1.17) may best be accounted for with replacement costs instead of straight line depreciation.

Calculating price element 5: Indirect fuel infrastructure. In this study, indirect fuel infrastructure costs were limited to the contract labor costs at one Naval Air Station. These are actual representative data but are highly conservative and a potential limitation to this study.

Recommendation: FBCF studies should include fully burdened labor costs such as proportional amount of installation support costs. The aviation FBCF calculations may leverage an ongoing Naval Supply Systems Command study quantifying costs for air station fuel delivery.

Calculating price element 7: Other service and platform specific costs. Price element seven, the force protection assets and personnel assigned to keep the hydrocarbons, physical and human resources secure, remains the most difficult element to determine. See follow on studies section for this price element calculation recommendation.

D. COMPUTING AN LCC ESTIMATE WITH A REALISTIC O&S LIFE CYCLE

Cost estimation methods can be used to overcome data shortfalls. The NCCA acknowledges and publishes specific data shortfalls in documentation available on the VAMOSC web site (www.navyvamosc.com). As an example applicable to this study, the VAMOSC database does not contain fuel consumed by F/A-18E/F for the first three years of the aircraft's deployment. We used a quantitative, time series, three-year moving average forecasting method to estimate fuel consumption data missing from VAMOSC FY99 to FY01 (Table 18). Estimation errors should have an insignificant effect on overall LCC results as estimated values represent less than one percent of the total life-cycle fuel consumed. There is no reason to believe that these estimations significantly distort the overall results.

CERs facilitate FBCF computations. We developed a statistically validated CER employed to project the LCC relationship of unknown future data. Using data relating fuel consumption to aircraft numbers, and assuming lifespan phase-out, we estimated fuel consumption for the platform of interest.

Recommendation: Future FBCF studies should strive to provide the cost estimation professional with libraries of applicable analogous data. Additional CERs should be developed to be used by cost estimators to determine TOC.

Realistic O&S life cycle yields program office estimates sophistication. We improved the estimate of life-cycle FBCF by predicting fuel demand over a realistic O&S phase created with actual data, deployment schedules through FOC and an airframe phaseout plan.

Recommendation: Use analogous actual data adjusted for technology improvements, planned deployment schedule through FOC, and lifespan based phaseout to predict the yearly fuel demand throughout a realistic O&S life-cycle. Services should use this display when they present Program Office Estimates required by the OSD(CAIG) cost estimation guide.

<u>The OSD Calculator V7 requires adjustment</u>: The newest calculator version assumes scenarios always require both escort vehicles and escort aircraft. Moreover, the calculator assumes only one delivery mode (T-AO/E, KC, or F/A-18E/F), whereas operationally, there is usually more than one mode of fuel delivery vehicle. Even existing modifications of the calculator, customized to the delivery environment, do not address a scenario involving multiple delivery vehicles or multiple delivery environments.

Recommendation: We recommend adding calculator documentation language discussing how to handle scenarios not requiring both escort vehicles and escort aircraft, thus nullifying nonexistent escort fuel demand and depreciation cost contributions. Also, we recommend modification of the V7 to handle more than one delivery mode. Modified calculator versions may be combined into a single file to accommodate scenarios for platforms that require multiple refueling platforms. The additive nature of the primary calculator outputs should be addressed in the documentation.

E. FOLLOW-ON STUDIES

The following future studies are necessary to refine policy, methodology, and cost estimations to advance the field of FBCF:

- Study routine existing and recommended new cost reports useful to FBCF computations, making recommendations to facilitate improved centralized data retrieval capabilities.

- Perform this study for an aviation platform deployed more extensively in a land based operational environment as well as the shipboard operational environment.
- Apply the newest FBCF calculator to a scenario involving air refueling delivery assets
- Create a model calculator which combines the scenario inputs for multiple fuel delivery vehicles
- Refine installation direct and indirect costs based on all major air stations to include additional levels of labor burdens.
- Perform sensitivity analysis to evaluate the impact of commodity price of fuel on investment decisions concerning fuel efficiency program.
- Perform a detailed study of price element seven that includes force protection and security personnel and personnel assigned to operate escort vehicles and aircraft.

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VI. APPENDICES

A. CORLEY THESIS COST ELEMENT DESCRIPTION

Excerpt describing the seven cost elements from Corley's Thesis, *Evaluating the Impact of the Fully Burdened Cost of Fuel,* September 2009.

Element	Burden Description
Commodity Cost of Fuel	DESC standard price for the appropriate type or types of fuel
Primary Fuel Delivery Asset O&S Cost*	Cost of operating service-owned fuel delivery assets including the cost of military and civilian personnel dedicated to the fuel mission.
Depreciation Cost of Primary Fuel Delivery Assets*	Measures the decline in value of fuel delivery assets with finite service lives using straight-line depreciation over total service life
Direct Fuel Infrastructure O&S and Recapitalization Cost*	Cost of fuel infrastructure that is not operated by DESC and directly tied to energy delivery
Indirect Fuel Infrastructure*	Cost of base infrastructure that is shared proportionally among all base tenants
Environmental Cost*	Cost representing carbon trading credit prices, hazardous waste control and related subjects.
Other Service & Platform Delivery Specific Costs*	Includes potential cost associated with delivering fuel such as convoy escort, force protection, regulatory compliance, contracting and other costs as appropriate.

* These costs vary by Service and delivery method (ground, sea, air)

Table 1. OUSD(AT&L) defined cost elements for estimating the FBCF (DAG, 2009, p. 4)

1. Commodity Cost of Fuel: DESC is DoD's sole source for petroleum products, coal, natural gas, and electricity within the continental United States and serves as the integrated material Manager for all petroleum procurement and distribution from wholesale points to units of the Services. The commodity cost of fuel is the standard price, established by DESC, for fuel received at a retail POS and includes a surcharge to recover costs associated with storage and transportation of the fuel to the retail POS (Figure 1). The Services receive delivered fuel through a reimbursable arrangement called the Defense Working Capital Fund (WCF). Current standard prices are found at the DESC Web site (http://www.desc.dla.mil/).

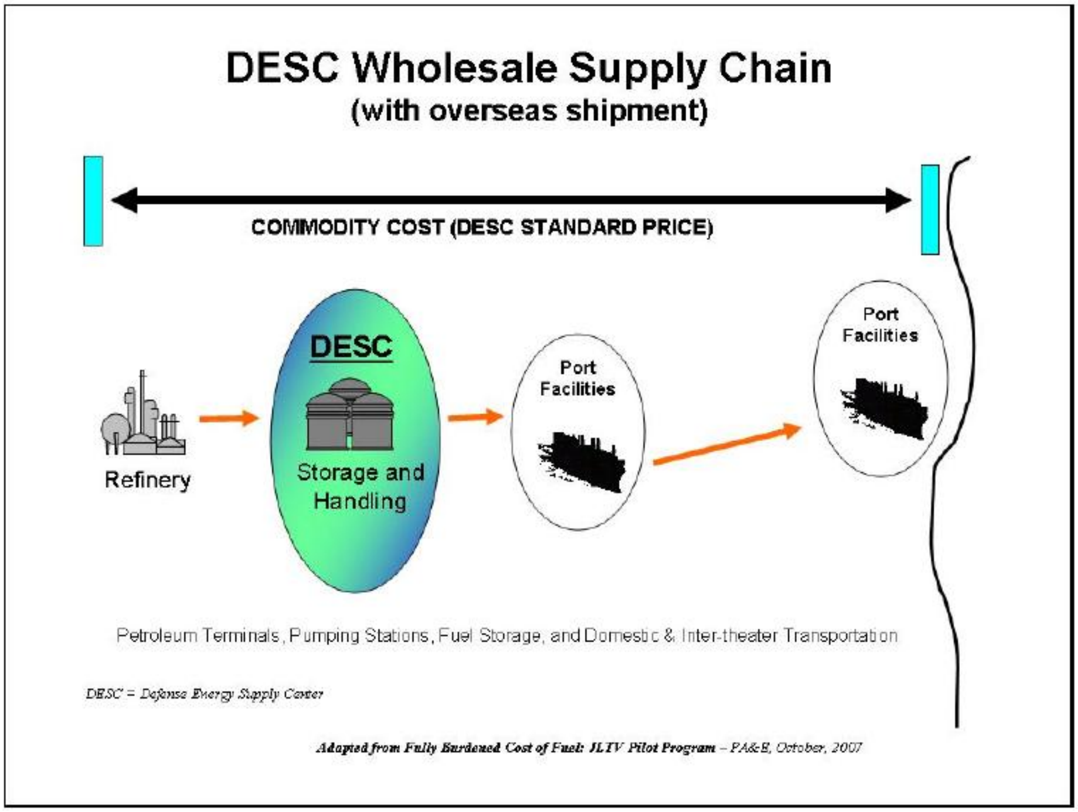

Figure 1. DESC wholesale supply chain (DAG, 2009, p. 5)

DESC's standard price for fuel is not a current market price for fuel, but a financial tool intended to insulate the Services from global fuel price volatility. The standard price is calculated far ahead of the fiscal year that it will be used based on an eighteen-month fuel price projection. Thus, during market swings the difference between market price and the standard price of fuel may result in a net gain or loss to the WCF (DAG, 2009).

2. Fuel Delivery Asset Operations & Support Cost: Operating & Support (O&S) costs are those costs associated with fuel delivery assets (major delivery vehicles such as oiler vessels, aerial refueling aircraft and tanker trucks) operated by the Services

from the retail POS after receipt from DESC. O&S costs consist of operations and maintenance (O&M) of the assets and the costs for military and civilian personnel dedicated to fuel delivery. For delivery assets that are major systems (e.g., oilers and aerial refueling aircraft) these costs are available via the Service-specific Visibility and Management of Operating and Support Costs (VAMOSC). For Navy, the information can be obtained at Web site (http://www.navyvamosc.com/).

3. Fuel Delivery Asset Depreciation Costs: Though most DoD studies assess equipment recapitalization, these costs provide a measure of the decline in capital value of the primary fuel delivery assets over time. OUSD(AT&L) suggests using straight line depreciation over the expected service life of the asset for calculating this cost element.

4. Direct Fuel Infrastructure: Applying only to infrastructure operated by the Services, this cost element captures the O&S and recapitalization costs for facilities in-theater and not operated by DESC. Data and associated cost factors for DoD infrastructure are centrally managed by the Office of the Under Secretary of Defense (Installations and Environment) (OUSD(I&E)). Data on all DoD world-wide facilities from the Facilities Assessment Database is available to registered users of the OUSD(I&E) Facilities Program Requirements Suite at Web site (http://www.acq.osd.mil/ie/).

5. Indirect Fuel Infrastructure Costs: This cost element captures the fair share of the total indirect O&S costs attributable to base-level fuel infrastructure functions. OUSD(AT&L) suggests these costs be based on a per capita basis for base-level O&S by dividing the total installation manpower by the total annual base O&S costs to derive a per capita factor. This factor can then be applied to the Fuel Delivery Asset O&S Costs (above) to estimate an annual indirect fuel infrastructure cost.

6. Environmental Costs: The costs of fuel consumption related to the environment are difficult to quantify. However, a proxy has been adopted by the Office of the Secretary of Defense (Program, Analysis and Evaluation) based on costs associated with DoD environmental clean-up and hazardous material control, and the potential costs of carbon emission offsets.

7. Other Service/Platform Unique Costs: Costs for special considerations peculiar to the platform or system to be fielded such as DoD force protection assets allocated to the fuel delivery forces and their respective O&S costs, direct fuel costs, depreciation and manpower costs make up the final cost element. As evidenced in previous studies and echoed by OUSD(AT&L), these costs can become significantly greater than all others combined in high-risk operational scenarios.

B. BASE CASE COST ELEMENT DEVELOPMENTAL DATA

Effective Date	Price	Months	Days
July 1, 2008	$4.09	2	61
December 1, 2008	$2.51	2	62
February 1, 2009	$1.68	2	59
April 1, 2009	$1.46	5	153
September 1, 2009	$2.15	1	30
Weighted Average	$2.38	$2.17	$2.17
% difference from VAMOSC reporting method ($2.05)	16.00%	5.73%	5.86%
Source: DESC Standard Prices www.desc.dla.mil			

Table 13. FY09 DESC standard price data

Five different DESC standard prices were effective during FY09. Table 13 Table 13. displays numerical average of the five prices as well as weighted average price based on effective price over 12 months and 365 days respectively. These estimates vary from actual price per gallon referenced at $2.05 per gallon.

FY2008 Reported Costs for MSC Oiler Assets
Datea and Assumptions Provided by MSC Personnel

T-AO Ships Fleet Replenishment Oilers			**Total FY2009 Fuel Deliveries T-AO-T-AOE Fleet**		
Ship Quantity	Annual Revenue	Total Revenue	JP-5 Gallons	140,844,027	23.47%
5	$32,411,130	$162,055,650	DFM Gallons	459,194,607	76.53%
9	$33,972,120	$305,749,080			
Total Charge to Navy for T-AO Fleet		**$467,804,730**	**Assumptions:**		
			T-AO Percentage Time for Fuel Deliveries		95%
T-AOE Ships Fast Combat Support Ships			T-AOE Percentage Time for Fuel Deliveries		60%
Ship Quantity	Annual Revenue	Total Revenue	**Allocating Costs by Percentage:**		
4	$60,064,260	$240,257,040	T-AO Cost to Navy for Fueling Operations @ 95%		$444,414,494
Total Charge to Navy for T-AOE Fleet		**$240,257,040**	T-AOE Cost to Navy for Fueling Operations @ 60%		$144,154,224
			Total Fueling Operations Cost to Navy		**$588,568,718**
Total Charge for Combined T-AO/T-AOE		**$708,061,770**			
Fueling Portion Related to JP5 Delivery at 23.47%				**$138,151,751.64**	
Gallons JP5 Delivered				140,844,027	
MSC Cost of Delivery per Gallon				**$0.98**	
Converted to FY2009 @ 1.0181				**$1.00**	

Figure 9. MSC financial data for T-AO/E cost of delivery per gallon JP-5 (From NAVAIR, 2009)

Figure 9 displays the inflation adjusted MSC T-AO/E cost per gallon of delivered JP-5 at $1.00. In FY08, the MSC T-AO/E fleet delivered 140,844,027 gallons of JP-5, or 23.47 percent of all fuel delivered. Using NAVAIR/MSC estimation method assumptions for TAO and TAOE operations, the JP-5 portion of total fueling operations cost to Navy, the fueling portion involving JP-5 delivery was $138,151,752 (NAVAIR, 2009).

STEP 2: Primary Fuel Delivery Asset O&S Cost		
	On-Ground	In-Air
Cost (FY08 $)	$490,732,959	$4,888,952,844
Aviation Fuel Delivered (gal)	1,954,000,000	227,741,894
Cost Per Gallon	**$0.25**	**$21.47**
Ground (Source: 2001 Defense Science Board Study)		
Ground O&S Cost (FY99 $)	$409,700,000	
Aviation Fuel Delivered On-Ground (gal)	1,954,000,000	
Aerial (Source: AFTOC)		
MDS	O&S Cost (FY08 $)	
HC-130N	$69,523,455	
HC-130P	$170,124,957	
KC-10A	$1,174,129,054	
KC-135D		
KC-135E	$144,093,675	
KC-135R	$2,871,230,281	
KC-135T	$459,851,422	
TOTAL	$4,888,952,844	
Source: USAF Headquarters (AFCAA/FMF) FBCF Study (2009)		

Figure 10. USAF FBCF analysis for KC tanker delivery costs (From HQ USAF, 2009)

Figure 10 shows HQ USAF study with FY08 air refueling O&S costs per gallon at $21.47 (figures stated in FY08$).

Naval Tanker A/C Total FBCF Costs

Summary of FY2008 Naval Tanker Aircraft Fully Burdened Cost of Fuel Costs

	F/A-18E/F	KC-130J	KC-130T	KC-130R	S-3B	Totals
Tanker O&S Costs	$103,844,029	$62,409,757	$12,270,515	$3,323,657	$16,502,611	**$198,350,569**
Tanker Usage Depreciation	$96,721,094	$19,831,965	$8,401,851	$631,397	$5,273,089	**$130,859,397**
Total FBCF Tanker Costs	**$200,565,123**	**$82,241,722**	**$20,672,366**	**$3,955,054**	**$21,775,700**	
Hours Flying Tanker Missions	8,662.8	5,771.2	1,273.8	311.7	1,239.4	
Cost Per Tanker Usage Hour	**$23,152**	**$14,250**	**$16,229**	**$12,689**	**$17,570**	
Total Tanking Mission Flights	4846	2946	410	119	580	
Fuel Capacity - Buddy Store gallons	2,400				795	
Percentage of Fuel Dispersed B. Store	100%				100%	
External Store Waste Factor	25%				25%	
Fuel Capacity - Internal Gallons	2,048	12,140	12,140	12,140	1,933	
Percentage of Fuel Dispersed Internal	0%	53%	46%	51%	23%	
Internal Fuel Waste Factor		5%	5%	5%	5%	
Gallons Dispersed	8,722,800	17,201,648	2,035,574	661,959	550,702	**29,172,683**
Calculated Cost Per Gallon O&S Cost	**$11.90**	**$3.63**	**$6.03**	**$5.02**	**$29.97**	**$6.80**
Calculated Cost Per Gallon Deprec Cost	**$11.09**	**$1.15**	**$4.13**	**$0.95**	**$9.58**	**$4.49**

Data Sources:
Hours and Tanking Mission Flights taken From FY2008 Reported usage in Deckplate DP-4001 TMR Reports
Platform O&S Costs Taken From VAMOSC-ATMSR Reporting for FY2008 Per Flight Hour Times Tanker Mission Flight Hours
Depreciation Costs Taken From AIR-4.2 Ser 06 Nov 2008 Avg A/C Costs For Equivalent Aircraft Quantities Based on Percentage Use
Fuel Capacities Taken from Respective T/M/S NATOPS Manuals

Assumptions:
Buddy Stores including ARS and External Tanks Emptied Before Landing (assumed External Waste Factor of 25% for dumped fuel)
F/A-18 E/F Would not Tank from Internal Fuel Capacity Whereas S-3B with Longer Range Can Do so
S-3B and KC-130 Variants would have Some Wastage from Internal Fuel Transfer Because of Hook up to Transfer
% Internal Fuel Use Based on Deducting avg gallons per hour times avg mission length plus 1 hour safety margin with 2/3rds of remaining dispersed
For S-3B Used 1/2 Hour Safety Margin

15

Figure 11. NAVAIR FBCF analysis for F/A-18E/F tanker delivery costs (From NAVAIR, 2009)

Figure 11 shows NAVAIR study with FY08 F/A-18E/F O&S costs per gallon at $11.90, and depreciation cost at $11.09 per gallon, inflated at Navy O&M factor of 1.0181

Line	Cost Type	NAS Lemoore FY09 Infrastructure Costs	
A	Direct	Fuel Truck Lease	$ 907,476
B	Direct	Misc Supplies & Equip	$ 89,700
C	Indirect	Fuel Division Labor	$ 2,027,024
D	Basis	Gallons of Fuel Delivered	43,747,378
(A+B)/D	Direct	Infrastructure $/gal	$ 0.02
C/D	Indirect	Infrastructure $/gal	$ 0.05
(A+B)/C	Ratio	Direct to Indirect (#)	0.4919
Source: NAS Lemoore N31			

Table 14. FY09 NAS Lemoore representative infrastructure costs

F/A-18 E/F OPTEMPO Category Summary						
	Operational		Steady State			
Code	Category	Hours	Category	Hours	SS Total Hours	
1			Land Operations Non Deployed*	65,816.0	Land Hours	
2	Land Operations Deployed*	161.4			65,892.5	
3			FRS Land Operations	76.5	79.13%	
A			Ship Operations Non-Deployed	17,378.1	Ship Hours	
B	Ship Operations Deployed	33,279.8			17,378.1	
C			FRS Ship Operations+	0.0	20.87%	
	Total Operational (2+B)	33,441.2	Total Steady State (1+3+A+C)	83,270.6	83,270.6	
	Percent Operational	28.65%	Percent Steady State	71.35%	100.00%	
Source: NAVAIR from FY2008 DeckPlate DP-0014 Reports						
*	Hours adjusted to compensate for Japan squadrons Steady State land hours logged as deployed					
+	F/A-18E/F FRS Ship Operations hours logged as Ship Operations Non-deployed hours					

Table 15. FY08 F/A-18E/F representative Operational vs. Steady-state hours

Shipboard Flight Hour Allocations		
Code	Category	Hours
1	Land Operations Non Deployed	1,091,951.3
2	Land Operations Deployed	115,277.4
3	FRS Land Operations	16,795.5
A	Ship Operations Non-Deployed	35,587.5
B	Ship Operations Deployed	103,241.1
C	FRS Ship Operations	228.4
	Total Land Operation Hours	1,224,024.2
	Land Ops Percentage	89.8%
	Total Ship Operation Hours	139,057.0
	Ship Ops Percentage	10.2%
Source: NAVAIR from FY2008 DeckPlate DP-0014 Reports		

Table 16. FY08 Shipboard Flight Hour Operations for all Navy aircraft

C. FBCF CALCULATOR V2 INPUTS AND OUTPUTS

Cost Element	C1	C2	C3	C4	C5	C6	C7 (UB)
All units are ($/gal)	Commodity Cost of Fuel	Fuel Delivery O&S Cost	Depreciation Cost of Fuel Delivery Assets	Direct Fuel Infrastructure O&S Cost	Indirect Fuel Infrastructure O&S Cost	Environmental Cost	Other Costs (Upper bound)
Operational Input	$ 2.05	$ 13.80	$ 0.59	$ 0.36	$ 0.73	$ 0.10	$ 4.10
Steady-State Input	$ 2.05	$ 2.88	$ 0.12	$ 0.02	$ 0.19	$ 0.10	$ 0.05
Operational Scenarios							
Upper Bound	$ 2.26	$ 15.18	$ 0.65	$ 0.40	$ 0.80	$ 0.11	$ 4.10
Mean	$ 2.06	$ 13.87	$ 0.59	$ 0.36	$ 0.73	$ 0.10	$ 2.31
Lower Bound	$ 1.87	$ 12.56	$ 0.54	$ 0.33	$ 0.66	$ 0.09	$ 0.51
Steady-State Scenarios							
Upper Bound	$ 2.26	$ 3.17	$ 0.13	$ 0.02	$ 0.21	$ 0.11	$ 0.05
Mean	$ 2.06	$ 2.89	$ 0.12	$ 0.02	$ 0.19	$ 0.10	$ 0.04
Lower Bound	$ 1.87	$ 2.62	$ 0.11	$ 0.02	$ 0.17	$ 0.09	$ 0.02

OPTEMPO Relationship	Ops/SS Ratio (R)	Operational Proportion (P_{Op})	Steady-State Proportion (P_{SS})	Op Demand (D_{Op}) (gal/day)	SS Demand (D_{SS}) (gal/day)
Upper Bound	29%	100%	100%	169,199	252,174
Mean	29%	100%	100%	168,353	250,913
Lower Bound	28%	99%	99%	167,507	249,652

	Operational		Steady-State		OPTEMPO Weighted	
	$FBCF_{SOp}$	$FBCF_{DOp}$	$FBCF_{SSS}$	$FBCF_{DSS}$	$FBCF_S$	$FBCF_D$
	$/gal	$/day	$/gal	$/day	$/gal	$/day
Mean	$ 20.01	$ 3,368,214.18	$ 5.47	$ 1,372,600.51	$ 9.62	$ 1,941,471.99
Median	$ 19.99	$ 3,364,607.28	$ 5.47	$ 1,372,603.91	$ 9.61	$ 1,940,939.51
Std Dev	$ 1.32	$ 223,042.40	$ 0.20	$ 49,557.06	$ 0.41	$ 73,310.10
Mean + 1.65 Std Dev	$ 22.19	$ 3,736,234.13	$ 5.80	$ 1,454,369.66	$ 10.29	$ 2,062,433.65
Mean - 1.65 Std Dev	$ 17.82	$ 3,000,194.22	$ 5.15	$ 1,290,831.37	$ 8.95	$ 1,820,510.33

Table 17. Representative Base Case cost estimate (subsequent Monte Carlo run)

Table 17 Notes:
1. Cost elements are the input from deterministic calculations in section IV.B.
2. OPTEMPO relationship began with 100 percent of a known by F/A-18E/F operational demand, not a system percentage of total location demand.
3. Mean operational, steady-state and OPTEMPO weighted $FBCF_S$ in Table 17 differ slightly from the values presented in section IV.B. Subsequent Monte Carlo simulation runs adjust slightly with variable random numbers generation.

D. IMPROVED LCC COST ESTIMATION RELATIONSHIP DATA

F/A-18 E/F Aircraft Force Structure and Fuel Consumed Actual FY98-FY09 and Projected FY10-FY19				
Year	Gallons Consumed	APDF ver 105	VAMOSC "Regular" E/F Count	VAMOSC Aircraft Count
1998	0		0	0
1999	2,525,135		6	7
2000	8,959,708		2	24
2001	19,457,444		18	53
2002	29,391,180		50	86
2003	50,563,338		72	123
2004	58,203,306		106	167
2005	93,100,518		155	209
2006	112,927,584		191	255
2007	136,638,390		216	286
2008	149,851,128	227	242	331
2009	153,800,976	237	260	358
2010	157,818,607	239	263	355
2011	160,368,145	243	267	361
2012	159,093,376	241	265	358
2013	168,866,605	257	282	381
2014	176,090,296	268	295	398
2015	176,090,296	268	295	398
2016	176,090,296	268	295	398
2017	173,115,835	268	290	391
2018	165,892,144	268	277	374
2019	153,569,377	268	255	345
FY99-19	2,482,413,684			
Source: VAMOSC 2001-2004, 2005-2009, CNAF 2008-2017, APDF 2010-2019				

Table 18. F/A-18E/F Aircraft end strength and fuel consumed data FY98–19

Projected F/A-18E/F Aircraft End Strength and Fuel Consumed		
Year	Gallons Consumed	VAMOSC Aircraft Count
2020	139,546,918	312
2021	123,824,767	275
2022	105,128,155	231
2023	87,281,389	189
2024	67,734,931	143
2025	54,562,318	112
2026	35,440,783	67
2027	23,967,862	40
2028	25,242,631	43
2029	22,693,093	37
2030	23,967,862	40
2031	14,194,633	17
2032	-	0
FY20-32	723,585,342	
FY99-32	3,205,999,026	

Table 19. F/A-18E/F Aircraft end strength and fuel consumed data FY20–31

Table 18 and Table 19 provide supporting data for the normally distributed estimated life-cycle fuel consumed and aircraft count in Figure 7. Highlighted cells are estimates based on reverse forecasting techniques for missing FY99-FY01 fuel consumption, ratio inference for VAMOSC total aircraft count, and CER for gallons consumed. Phasing out of the aircraft count is based on an 18 year lifespan assumption. Fiscal Years 2008 and 2009 aircraft count in column APDF were actual squadron assigned counts. Using the relationship between APDF count and VAMOSC total count, we infer the VAMOSC total count is on average 1.484 times the APDF count. We apply this ratio to the published APDF projected count FY10 through FY17 to estimate the total VAMOSC Aircraft count. The aircraft introduced in each year beginning in FY99 depart from service starting FY17, 18 years after delivery. As an example calculation, in FY17, the end strength aircraft count is estimated to be 391 as in equation (VI.1).

$$FY17 = FY16 - (FY99 - FY98) = 398 - (7 - 0) = 391 \tag{VI.1}$$

The aircraft count in Table 18 carries over to Table 19. We estimate the annual fuel consumed (dependent variable) based on the total aircraft count (independent variable) by using the regression CER created from VAMOSC FY05-FY09 data.

$$\begin{gathered} AnnualGalConsumed = \\ 6,970,942gal + 424,923gal / aircraft * VAMOSCAircraftCount \end{gathered} \tag{VI.2}$$

E. OUSD(AT&L) FBCF V7 CALCULATOR SCENARIO RESULTS

Price Element:		E1	E2	E3	E4	E5	E6	E7
(All Price Element units are $/gal)		Commodity Cost of Fuel (DESC)	Fuel Delivery O&S Cost	Depreciation Cost of Fuel Delivery Assets	Direct Fuel Infrastructure O&S Cost	Indirect Fuel Infrastructure O&S Cost	Environmental Cost	Other Costs (Force Prot. etc.)
Operational Scenario Prices:		OP_1	OP_2	OP_3	OP_4	OP_5	OP_6	OP_7
	5%	$2.05	$4.12	$19.24	$0.36	$0.73	$0.10	$1.86
	Mean	$2.05	$4.35	$19.95	$0.36	$0.73	$0.10	$2.04
	95%	$2.05	$4.57	$20.66	$0.36	$0.73	$0.10	$2.45
Steady-State Scenario Prices:		SP_1	SP_2	SP_3	SP_4	SP_5	SP_6	SP_7
	5%	$2.05	$2.88	$0.12	$0.02	$0.19	$0.10	$0.04
	Mean	$2.05	$2.88	$0.12	$0.02	$0.19	$0.10	$0.04
	95%	$2.05	$2.88	$0.12	$0.02	$0.19	$0.10	$0.04
Scenario Parameters:		OPTEMPO Ratio (*OR*)	Operational Proportion (P_O)	Steady-State Proportion (P_S)	O Demand (D_O) (gal/day)	S Demand (D_S) (gal/day)	Number of Vehicles in O Unit (N_O)	Number of Vehicles in S Unit (N_S)
	5%	29%	57.7%	83.0%	601,693	550,000	112	108
	Mean	29%	57.7%	83.1%	620,499	550,000	112	108
	95%	29%	57.7%	83.1%	639,305	550,000	112	108
Results:		**Major Operations**		**Steady-State**		**Duty-Cycle Weighted (per vehicle)**		
		ADP_O	***$FBCF_O$***	***ADP_S***	***$FBCF_S$***	***ADP***	***FBCF***	**Demand**
		$/gal	**$/day**	**$/gal**	**$/day**	**$/gal**	**$/day**	**gal/day**
	5%	$28.57	$91,943	$5.40	$22,825	$12.13	$42,918	3,442
	Mean	$29.57	$94,481	$5.40	$22,843	$12.42	$43,654	3,514
	95%	$30.58	$97,018	$5.40	$22,862	$12.72	$44,389	3,586

Table 20. OUSD V7 FBCF report inputs and results

Symbol	Name	Units	5%	Mean	95%
OP_2	**Operational Price Element 2 (*OP_2*), Delivery Asset O&S Cost:**	$/gal	$4.12	$4.35	$4.57
OP_3	**Operational Price Element 3 (*OP_3*), Depreciation Cost of Fuel Delivery Assets:**	$/gal	$19.24	$19.95	$20.66
OP_7	**Operational Price Element 7 (*OP_7*), Other Costs:**	$/gal	$1.86	$2.04	$2.45
Intermediate Computed Values:					
L	Fuel Loaded out from DESC terminal	gal	946,759	981,838	1,016,918
α	Additional amount of fuel loaded out due to interdiction	gal	5,175	5,341	5,506
N_V	Number of delivery Vehicles needed to deliver fuel load-out	#	6	6	6
N_E	Number of Escort vehicles needed to protect delivery vehicles	#	2	2	3
N_A	Number of escort Aircraft needed to protect delivery vehicles	#	3	3	3
C_V	Total Fuel Consumed by delivery Vehicles	gal	284,102	298,552	313,510
C_E	Total Fuel Consumed by Escort vehicles	gal	73,590	84,599	102,739
C_A	Total Fuel Consumed by escort Aircraft	gal	0	0	0

Table 21. Operational price elements and intermediate computed values

F. OUSD(AT&L) FBCF V7 CALCULATOR DOCUMENTATION

Below are excerpts from the pre-decisional FBCF V7 calculator applicable to the Microsoft Excel file modified for at-sea delivery with delivery vehicles escorted and interdicted:

Price Element Computations:

Numerical estimates of some of the 14 Price Elements may be adequately determined through traditional cost estimating techniques. In some cases, contract prices may be used to define either the steady-state or operational Price Elements. However, for most operational scenarios, these figures are typically not computed. The three, most significant, operational Price Elements are related to *Operational Price Element 2, Delivery Asset O&S Cost* (OP_2)*, Operational Price Element 3, Depreciation Cost of Primary Fuel Delivery Assets* (OP_3)*,* and *Operational Price Element 7, Other Costs* (OP_7)*.* Element OP_2 reflects the operational and support costs of the delivery vehicles (including the manpower to operate them) to transport the fuel from the DESC delivery port/terminal out to the operational area where it is finally loaded into the combat vehicle. Price Element OP_3 includes the cost of procuring the delivery vehicles and the value lost, if they are destroyed during an attack. Price Element OP_7 largely reflects the costs incurred by the force protection assets and personnel used to ensure the safe transport and return of the delivery vehicles from the DESC port/terminal out to the operational delivery point and back. These three Price Elements have the greatest influence on the magnitude of the FBCF. The following method defines how these three critical Price Elements are computed in the FBCF Calculator.

The following table lists the parameters used to compute Price Elements OP_2, OP_3, and OP_7. All these parameters are on a single platform basis.

Parameter	Symbol	Units
Fuel Consumption Rate by 1 delivery Vehicle	CR_V	gal/day
Fuel Consumption Rate by 1 Escort vehicle	CR_E	gal/day
Fuel Consumption Rate by 1 escort Aircraft	CR_A	gal/day
Number of days to deliver fuel (round-trip)	T	days
Multiplier to keep convoy fuel flowing	A	#
Capacity of one delivery vehicle	Q	gal
Total Life-Cycle Cost (LCC) of 1 delivery Vehicle (Peacetime estimate)	TC_V	$
Procurement Cost fraction of delivery Vehicle LCC	PC_V	#
O&S cost fraction of delivery Vehicle LCC	OS_V	#

Table 1. Input Parameters for OP_2, OP_3, and OP_7 (continues on next page)

Parameter	Symbol	Units
Probability of interdiction during any one mission	Pi	#
Number of delivery vehicles Lost during the interdiction	λ	#
LCC Multiplier to account for accelerated operational usage of delivery Vehicle	LM_V	#
Average age of a delivery vehicle	M_μ	days
Number of delivery days 1 delivery Vehicle will be used during its lifetime	M_V	days
Total life-cycle Cost of 1 Escort vehicle	TC_E	$
LCC Multiplier to account for operational usage of Escort vehicle	LM_E	#
Escort Ratio (delivery vehicles per Escort vehicle)	ER_E	#
Number of escort days 1 Escort vehicle will be used in its lifetime	M_E	days
Total life-cycle Cost of 1 escort Aircraft	TC_A	$
LCC Multiplier to account for operational usage of escort Aircraft	LM_A	#
Aircraft Escort Ratio (delivery vehicles per escort aircraft)	ER_A	#
Number of days 1 escort Aircraft will perform escorts during its lifetime	M_A	days

Table 1. (cont.) Input Parameters for OP_2, OP_3, and OP_7

Price Elements OP_2 and OP_3 are related to the Life-Cycle Cost (LCC) of the delivery vehicles. OP_2 reflects the operating and support (O&S) costs, while OP_3 captures the procurement costs.

The OP_2 Price Element, the O&S fraction of the Total LCC used each day of a delivery mission, is based upon the Total LCC, TC_V. However, because the LCC is typically estimated for peacetime usage, and operational usage generally incurs O&S costs several times the peacetime estimate; the O&S portion needs to be multiplied by the LCC multiplier factor, LM_V. Also, since OP_2 only accounts for the O&S portion of the LLC, the entire TC_V is not used. The OS_V factor represents the O&S cost portion of the LLC and is used to ensure only the O&S portion of the LLC is included in the OP_2 calculation.

To finally compute the OP_2 Price Element, the TC_V is adjusted as follows to arrive at the *Primary Fuel Delivery Asset O&S Cost*, in units of $/gal for one delivery trip:

$$OP_2 = \frac{\left(T * N_V * \frac{OS_V * LM_V * TC_V}{M_V}\right)}{D_O} \qquad \text{(Eq. 1.16)}$$

Where:

$T =$ Number of days to deliver fuel (round-trip) (days)
$N_V =$ Number of delivery Vehicles needed to transport *L* amount of fuel
$OS_V =$ O&S cost fraction of delivery Vehicle's LCC
$LM_V =$ LCC Multiplier to account for operational usage of delivery Vehicle
$TC_V =$ Total Life Cycle Cost (LCC) of delivery Vehicle determined in peacetime ($)
$M_V =$ Number of days a delivery Vehicle will be used in its lifetime (days)
$D_O =$ Quantity of fuel Demanded per day by all users at the final delivery location (gal)

Price Element OP_3 measures the value of the fuel delivery assets during the time period they are used in one fuel delivery mission. Using the Total LCC as a start, it is multiplied by the Procurement Cost Factor PC_V, which is the proportion of the LCC that is composed of the procurement costs, to arrive at an estimate of the procurement cost alone. This procurement cost is divided by the number of days in the life of this asset to arrive at a value for the delivery asset on a per-day of use basis.

During delivery, there is a distinct possibility that the enemy will attack the fuel delivery vehicles. This model only accounts for losses to the delivery vehicles. Any losses to the escorting vehicles are not included. Services may wish to include these additional costs, but must be aware of properly apportioning the value of the escorts related purely to fuel delivery operations.

The probability of such an attack is defined as *Pi*. Given that such an attack occurs, the number of delivery vehicles destroyed is measured by the parameter lambda (λ). The value of the vehicles destroyed is based on the remaining life of the vehicle ($1-M_\mu/M_V$). The value lost due to attack is thus the product of *Pi*, λ, the life remaining factor, and the procurement cost.

To finally compute the OP_3 Price Element, the fraction of the procurement cost used each day of a delivery mission (from above) is combined with the number of delivery assets used (N_V) and the number of days they are used (T), plus the value of the loss due to interdiction, all divided by the amount of fuel demanded, to arrive at the *Depreciation Cost of Primary Fuel Delivery Assets*, in units of $/gal for one delivery trip:

$$OP_3 = \frac{\left(T * N_V * \frac{PC_V * TC_V}{M_V}\right) + \left[Pi * \lambda * \left(1 - \frac{M_\mu}{M_V}\right) * PC_V * TC_V\right]}{D_O} \qquad \text{(Eq. 1.17)}$$

Where:

$T =$ Number of days to deliver fuel (round-trip) (days)
$N_V =$ Number of delivery Vehicles needed to transport *L* amount of fuel
$PC_V =$ Procurement Cost fraction of delivery Vehicle LCC
$TC_V =$ Total Life Cycle Cost (LCC) of delivery Vehicle determined in peacetime ($)
$M_V =$ Number of days a delivery Vehicle will be used in its lifetime (days)
Pi = Probability of an interdiction event during a delivery mission
λ = Expected number of delivery vehicles that will be destroyed during the interdiction
$M_\mu =$ Average age of a delivery vehicle (days)
$D_O =$ Quantity of fuel Demanded per day by all users at the final delivery location (gal)

The *Other Costs* Price Element, OP_7, is largely composed of the costs associated with force protection of the delivery assets. It is assumed that the force protection contingent is directly proportional to the size of the delivery fleet (N_V). A greater number of delivery vehicles (N_V) will require a greater number of imbedded escort vehicles (N_E) and overhead protection aircraft (N_A). The issue of force protection may merit a complete sub-model to address the complexities of defending the delivery vehicles. This calculator model uses simple proportions in equations 1.4 and 1.5 to indicate where this issue plays a role in the FBCF calculation to compute the value for OP_7.

The appropriate LCC Multipliers (LM_x) for the escort vehicles and aircraft are used to adjust the peacetime derived LCCs. All other variables are as defined in Table 1. The following equation shows how the parameters are combined to produce the OP_7 cost, in units of $/gal for one delivery trip:

$$OP_7 = \frac{T * \left\{\left[N_E * \left(\frac{LM_E * TC_E}{M_E}\right)\right] + \left[N_A * \frac{(LM_A * TC_A)}{M_A}\right]\right\}}{D_O} \qquad \text{(Eq. 1.18)}$$

Where:

$T =$ Number of days to deliver fuel (round-trip) (days)
$N_E =$ Number of Escort vehicles needed to protect delivery vehicles
$LM_E =$ LCC Multiplier to account for operational usage of Escort vehicle
$TC_E =$ Total life-cycle Cost of 1 Escort vehicle ($)

$M_E =$ Number of escort days 1 Escort vehicle will be used in its lifetime (days)

$N_A =$ Number of escort Aircraft needed to protect delivery vehicles

$LM_A =$ LCC Multiplier to account for operational usage of escort Aircraft

$TC_A =$ Total life-cycle Cost of 1 escort Aircraft ($)

$M_A =$ Number of days 1 escort Aircraft will perform escorts during its lifetime (days)

$D_O =$ Quantity of fuel Demanded per day by all users at the final delivery location (gal)

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